PROFILE
Aircraft

250

Aérospatiale/BAC Concorde

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Norman Barfield MSc CEng AFRAeS MIMechE MAIAA

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46 Nakajima Ki-43 Ha
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48 de Havilland Vamp
49 Nieuport N.17
50 Sopwith 7F.1 Snip
51 Gee Bee Racers
52 de Havilland Mosq
53 Grumman F4F-3 W
(XF4F-1/7) & (F
54 English Electric Ca
55 Fokker Dr I (triplan
56 Fairey Flycatcher
57 Hawker Hart (& Ha
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84 Short C-Class Boat
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85 R.E.8
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(& RF-84F Thunderflash)
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bishi A6M5/8 'Zero-Sen'
ke 52') (see Nos. 129 & 190)
F.2B Fighter (see No. 21)
.F: 1918-30s)
an MiG-21 variants
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ought) A-7A/E Corsair II
Barracuda Mks.I-V
D3A ('Val') & Yokosuka D4Y
udy') Carrier bombers
nters (Yugoslavia: 1930-40s)
243 Avro (Hawker Siddeley)
Shackleton MR.1-3
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Ariete & Re.2005 Sagittario
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246 Supermarine Spitfire (Griffons)
Mks.XIV/XIX & XVIII
247 Martin (General Dynamics)
B-57A/G Canberra
248 de Havilland D.H.9A
(RAF: 1918-30s)
249 Douglas R4D Skytrain variants
(USN's DC-3/C-47s)
250 ? ? ? (To be announced)
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Concorde

Aircraft Profile No. 250: Aérospatiale/BAC Concorde can be regarded as a 'Special', not only because of our recent 50-nations' Competition to guess its title, and the fact that is has 50 per cent more pages, but also because it is the story of the conception of the newest and most exciting era in the history of commercial air transport development.

As 'Editorially Speaking' No. 17 (Profile No. 246) said: 'It is important . . . that the No. 250 Profile will be seen to be what—so far, alas—no-one else has attempted, namely, a middle course which tries to answer the burning questions (about Concorde) without fear or favour.'

With this unique objective for a Profile, No. 250 is a chronicle of the industrial and political evolution of Concorde as well as the maker's technical and marketing philosophies and solutions—the aggregation being a well-documented and positive chronicle of the evolution of a dramatic new era of international collaboration as well as of air transport technology.

The Anglo-French Concorde is now clearly at the most crucial stage of its necessarily long gestation, but, as ES No. 17 said: 'Love it or hate it, the Concorde is now too big an investment for it to be scrapped overnight!'

Profile No. 250 recounts the variegated conceptual decade of Concorde. Now only Concorde itself can describe the next chapter—in which its evident potential to dramatically redraw the map of the world has to face up to the vascillating wills and fortunes of airlines and Governments in the contentious world of the 1970s and beyond.

John Hacker Publisher

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256 Vickers Wellesley Mks I & II
257 Udet U-12 Flamingo
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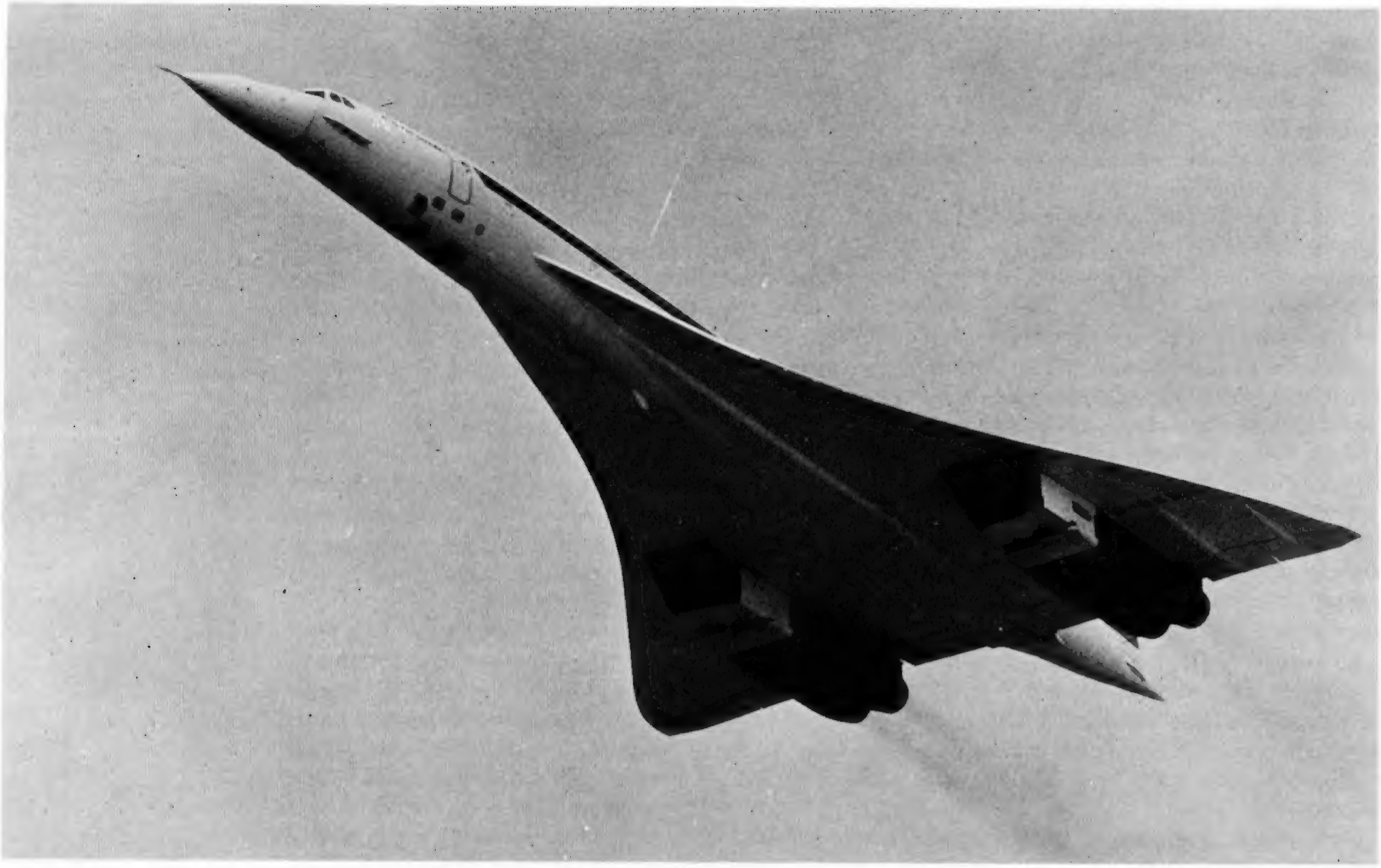


Aérospatiale/BAC Concorde

by Norman Barfield, MSc, CEng, AFRAeS, MIMechE, MAIAA

'Those projects which abridge distance have done most for the civilisation and happiness of our species.'

Macaulay (1800–1859)

Stripped of the inevitable extremes of emotion and criticism, the Anglo-French Concorde supersonic airliner is undeniably a supreme achievement by any standards. The world's first major international collaborative venture in advanced technology and the largest and most complex commercial programme ever undertaken by two nations in peacetime, Concorde has already pioneered international technological innovation and industrial collaboration on a grand scale and has restored to Europe undisputed leadership in the most advanced field of commercial aircraft development.

Conceived as the breakthrough generation of supersonic air travel, Concorde is now at the threshold of introducing the biggest step forward in the history of air transport. Twice as fast as todays jets, Concorde will halve intercontinental journey times and be faster than the sun. Significantly, it will also bring all the major populated land masses of the globe within the compass of 12 hours travel—mans natural day—and overcome the last major frontier of terrestrial travel.

Beyond sheer technology Concorde will thus dramatically shrink the world as we know it and will stimulate whole new social and industrial developments to add a new dimension to international life—without impairing the world environment.

In gestation as a feasible technical concept since the mid-1950s, Concorde became a formal international collaborative venture by the British and French Governments through their now historic Agreement of November 1962—with the physical programme responsibility vested in British Aircraft Corporation (BAC) and Bristol Siddeley (now part of Rolls-Royce) in the UK, and Sud-Aviation (now part of Aérospatiale) and SNECMA in France.

That Concorde has survived the political viscissitudes of these two major world powers for more than a decade is high testimony to the soundness of its concept and the success of the international collaboration and programme management involved. Moreover it has prefaced

Concorde 002 (G-BSST) showing the distinctive and characteristic ogival delta wing shape.

the international industrial implications of the enlarged European Economic Community (now that Britain has joined) by a full decade.

Paradoxically, while the Anglo-French Concorde has flourished, the United States—which has traditionally dominated long-haul air transport for more than 40 years—has so far failed to launch a significantly bigger, faster and more complex SST, whereas the USSR, the only other major world 'aerospace power', has independently conceived a virtually identical slender delta solution, the Tupolev Tu-144.

Crowned by the whole-hearted support of the British and French Governments, technical and performance capability substantially demonstrated, first customer airline contracts confirmed, and all manufacturing centres working on revenue-earning series production aircraft—Concorde is now an evident asset to European political and economic union and the envied leader of commercial aerospace technology worldwide.

As with any 'high-technology' programme contesting the frontiers of man's knowledge, Concorde has also created a big and ever-growing reservoir of significant 'spin-off' benefits to sharpen the spearhead of industry and commerce at large.

Concorde's progress to date—which has been aptly labelled *entente concordiale*—is a triumphant example of what two nations can achieve by working together and is an immensely encouraging portent of the industrial strength that European nations can achieve as partners spurred by the diffusive power of high technology.

Such progress has not been achieved without very considerable financial outlay—around £1,000 million—but the realization of a basic market expectation of 200 aircraft will bring a direct return of at least £4,000 million to the exchequers of Britain and France in vital export and foreign exchange earnings over the next decade—plus the inestimable value of the indirect benefits to society that will continue to flow from the new plateau of technology, commerce and internationalism that Concorde has established. And because any major advance on the basic Concorde concept—the hypersonic or sub-orbital transport—is clearly a '21st century science', Concorde developments can reasonably be foreseen that will go on to earn many times this sum for both nations fully to justify the investment and stabilise the progress of international air transport over the next 30 years or more.

It is inimical to the development of civilization that progress can be halted—it has to be guided. Concorde is the courageous exemplification of Britain and Frances ideas of how international air transport progress should be guided, and led, through the rest of this century and beyond.

Aside from its revolutionary and unprecedented impetus to world travel and communications, posterity will likely prove that Concorde has bequeathed an equally fundamental stimulus to mans progress through the outstanding success of the big international relationship that it has created in European industrial and political unity and future strength in the world.

The Concorde story told here is but an opening chapter because it has still only reached the end of the beginning—from conception to birth. Having successfully emerged from the most extensive and thorough development programme ever mounted for an airliner, Concorde now has to meet the challenge of the ever-toughening world of commercial air transport—which can be its only judge just as it has been its primary objective for the past decade.

The story of the maturity of Concorde will doubtless be the subject of more than one new *Profile* in the future.

Introduction

Concorde stemmed from an emerging belief in the mid-1950s—simultaneously in Britain and France—that the next major advance in international air travel could, and should, be at speeds beyond the so-called 'sound barrier'. Overcome by the imperatives of military technology in the battle for aerial combat supremacy fostered by the contemporary 'Cold War' in Europe, this barrier was now no longer considered an impassable obstacle to further significant advances in the prime asset of air transport—speed.

The relentless persuance of this imaginative ideology over the intervening years, and the massive technical and industrial pioneering that has necessarily resulted, is second only to that of the American Apollo Moon-landing programme. The progressive international co-operation is unique. Significantly, it has also prefaced the enlargement of the European Economic Community (EEC)—to include Britain—by a full decade.

The established Anglo-French Concorde supersonic airliner programme of today is the triumphant realisation of the objectivity of the aviation expertise and ultimately the political will of the two nations.

Now poised at the threshold of introducing the most significant and dramatic advance in the history of transport, Concorde has won for Europe the leadership in international air transport development so long dominated by the United States.

The Impact of Speed and the Significance of Time

It has been said that there is only one true economy—the economy of time.

Ever since the invention of the wheel, transport has been mans principal tool in his insatiable quest to annihilate distance in minimum time.

Speed—and hence the saving of time—has always been the *raison d'être* of transport and has motivated its spectacular progress to the forefront of mans basic needs.

When the heavier-than-air craft was invented at the dawn of the 20th century, speed was the least consequence. However, the evident military significance of speed was quickly appreciated in World War One, and the initiation of commercial air service in 1919 brought a whole new dimension to transport with its ability to transcend physical terrestrial barriers and so greatly extend mans travel potential.

Spearheaded by the exigencies of military necessity in World War Two and the development of the gas-turbine engine, the speed of commercial aircraft operation had increased ten fold—to the threshold of that of sound—as air transport development entered its fifth decade in 1960.

Dramatic increases in travel, trade and economic well-being naturally resulted throughout the world in the post-war years and air journeys have long since been measured in time rather than distance.

Speed continues to be the principal commodity that commercial aviation is in business to sell and increasing speed—combined with lower fares—the main impetus to traffic growth in the 1970's and beyond.

Thesis

The core of the makers case for Concorde is the exploitation of the benefits of speed and time-saving in the supersonic regime.

After more than a decade of stagnation in speed development, supersonic Concorde will again provide this vital stimulus to air transport. Its ability to cruise at twice the speed of sound—around 1,300 m.p.h. (2,092 k.p.h.)—means that long-distance air journey times will be halved at a stroke thereby setting it in a class apart from all other airliners cruising at a subsonic 600 m.p.h. (966 km./h.).

This means, the makers assert, that supersonic Concorde will be of special appeal to the 'time priority' traveller—notably the businessman—and provide a vital complement to the proliferate high-capacity subsonic jets. Hitherto both high-yield 'First' and the low-yield 'Tourist'/'Economy' class passengers have travelled together in the same vehicle, the fare differential being accommodated by the artifice of greater space and amenities for the higher fare passenger, but with no benefit in his real requirement—minimum journey time.

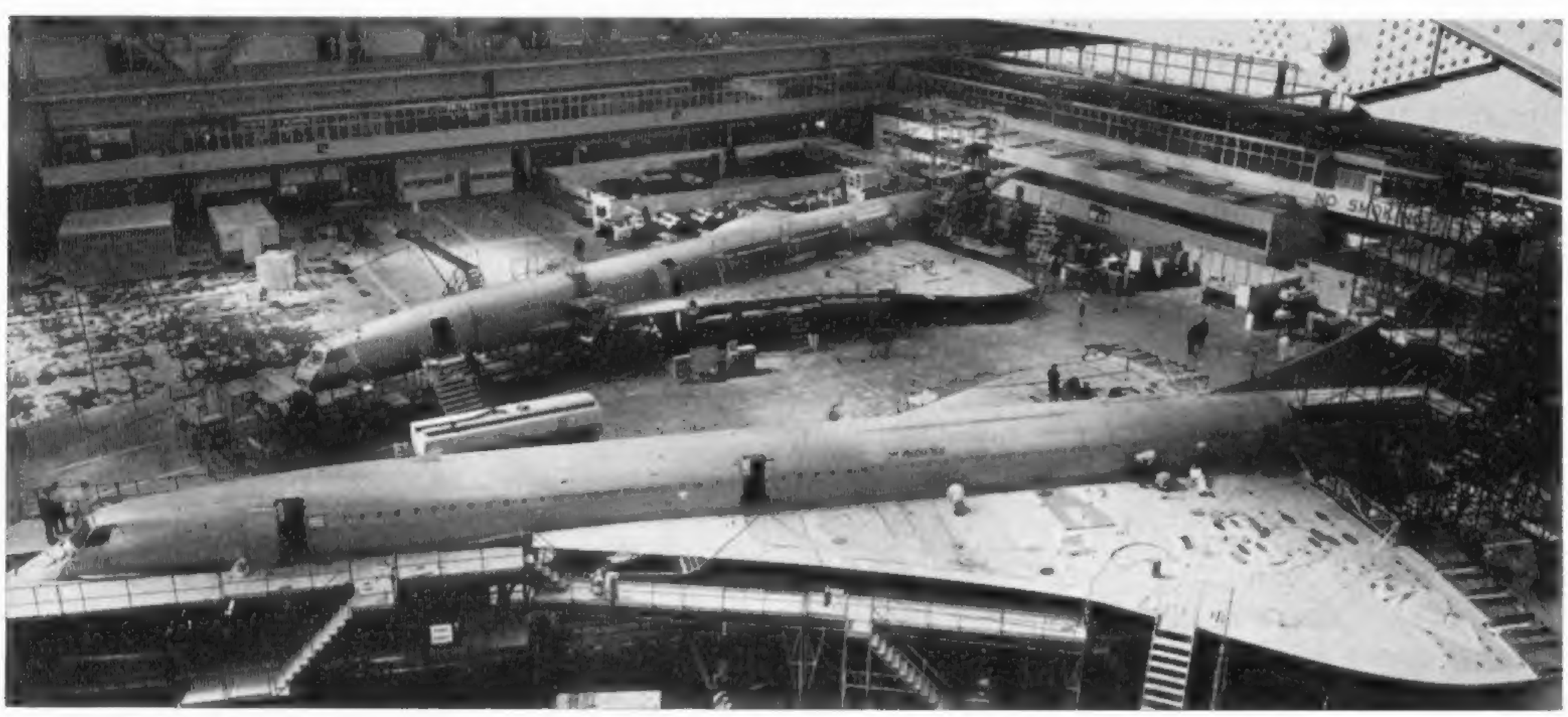
Additionally, the massive growth in tourism and leisure travel all over the world in recent years has generated a whole new generation of high-capacity subsonic jets to cater for this 'cost priority' mass travel market with a wide variety of low-fare and charter promotions and concessions.

Concorde—Time-Saver

Now comes Concorde to provide a 100 per cent speed advantage for the discriminating long-distance traveller. Halved journey times, less travel fatigue and physical disorientation, less time and accommodation expense away from base, and the new ability to bring many long-distance city pairs within the compass of a 'day-return' ticket—these are among the very real benefits that will amply justify the higher fare that he has always been prepared to pay for better service. Unlike the leisure traveller, who journeys in his own time, the businessman travels in what would otherwise be highly productive and remunerated office time. Concorde will thus dramatically reduce the present major imbalance in the cost/use of his time.

Significantly, while numerically a minority of the total traffic spectrum, business and other 'full-fare' regular travellers constitute the majority source of airline revenue—around 25 per cent of the total traffic, they produce around 40 per cent of total revenue.

Consequently Concorde will enable airlines



Concorde series production at the British final assembly centre at the Filton (Bristol) factory of the BAC Commercial Aircraft Division. Foreground: second production (202); background: fourth production (204)—first for BOAC.

to achieve greater profitability and versatility of operation through being able for the first time to provide a distinct choice of service for these two basic types of traveller.

Concorde also has the ability to bring all the major populated land masses of the globe substantially within the compass of a single days travel. As transport history has consistently shown, travel, trade and commerce increase dramatically when this becomes possible.

Within this exciting new global capability Concorde will equate the long haul air travel pattern of tomorrow with the short-haul journey times of today.

This, then, is the makers commercial thesis and justification for Concorde.

Vision

The impact of speed in transport and the advent and potential of the supersonic airliner were succinctly expounded and predicted by Sir George Edwards—architect and mentor of the Concorde programme—in his Presidential Address to the Royal Aeronautical Society delivered in February 1958.

History had consistently shown, Sir George said, that 'there is a definite connection between industry, population and speed of transport'. He then went on to develop a fundamental line of reasoning which accurately forecast the advent of the practical supersonic airliner—summarised in the following extracts.

'. . . the demand for more and faster transport was stimulated by the world's communities becoming industrialised. In the same way . . . the presence of more and faster transport enabled the world's communities to become industrialised and expand. There is a moral there somewhere.

'. . . increasing speed in transport has been the essential hand-maiden to increasing development all over the world and the only medium in which speed can continue to increase is in the air. There is no indication that a demand for increasing speed is going to diminish or disappear, so that the demand for faster aeroplanes is likely to go on.

'. . . subsonic jets will continue to do their 600 miles an hour or thereabouts right through the 1960s. There seems, however, to be no technical reason why the supersonic development of the World's Air Speed Record (and the supersonic bombers which could follow it) could not also be followed by supersonic transports, flying at speeds of over 1,000 miles an hour. If one decided that the previous gaps which had existed between the World's Air Speed Record and bomber speeds and transport speeds would be maintained, then there is no reason why civil jets should not be in existence at supersonic speeds in the 1960's. I believe, however, that the financial burden of depreciating the subsonic jets will alone make that impossible, and a supersonic jet in operation before 1970 is of academic interest only.

'What does emerge from a general study of business travel . . . is that when a destination gets beyond the 12 hour journey circle, journey incidence falls sharply. There is much business flying inside the '12 hour circle'—in fact half of it . . .

'When we do get a supersonic jet we get with it the ability to bring practically the whole world within reach of the 12 hour journey time.

'I have tried to show that there is an increasing demand for a longer distance to be flown in 12 hours. I am certainly convinced that nothing will stop the ultimate operation of long-range supersonic civil aeroplanes.'

This classical analysis of the significance and timing of the SST by Sir George Edwards proved to be both prescient and accurate—and an outstanding landmark in aviation literature.

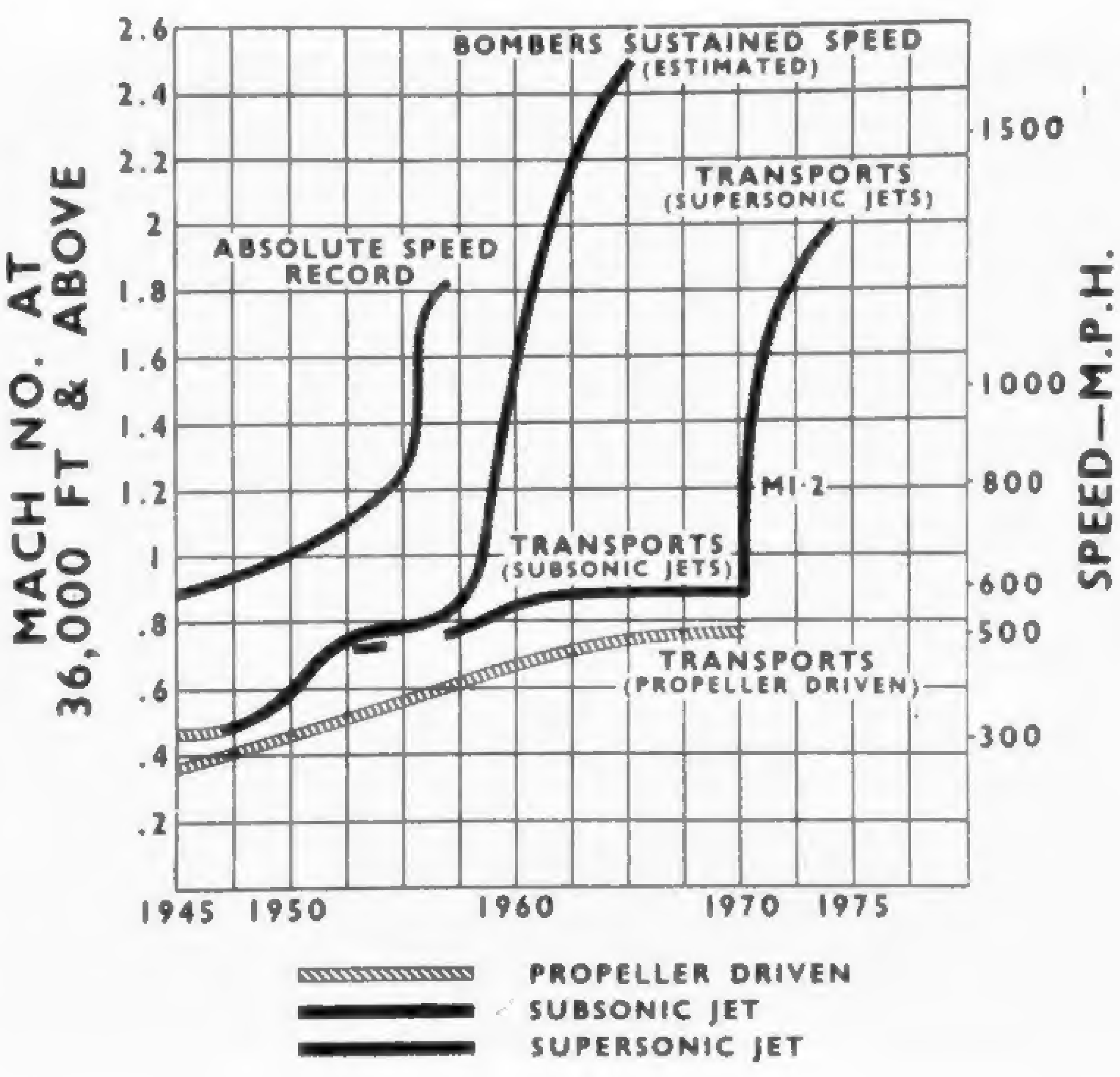
The Sonic Simile

Before tracing the technical, industrial and political evolution of Concorde, it is important to identify the significance of the speed of sound and the definition of the 'Mach Number'.

Man-made projectiles, such as bullets and shells, were being propelled through the atmosphere at supersonic speeds many generations before man himself had ever flown at all.

Sir Isaac Newton (1642–1727)—founder of the prime sciences of Dynamics and the Calculus—was the first to calculate the speed of propogation of pressure or sound in air—by measuring the time difference between the flash and the sound of a gun fired some distance away, on an artillery field near London. His finding, published in 1726, was that the velocity of sound in air was around 1,140 feet per second and that the square of the speed of the propogation is proportional to the ratio of the pressure change to the corresponding density change involved in the process.

The speed of sound was first attained by



Forecast of speed trends by Sir George Edwards in his Presidential Address to the Royal Aeronautical Society in February 1958. Note his forecast of a Mach 2 SST in 1974/5. However, as he has pointed out recently, the fact that the expected large long-range supersonic bomber did not materialise has meant that the majority of the technology required for Concorde has had to be obtained within its own development programme and without the traditional prior military experience.

military aircraft during the 1940s. The physical consequence of this was a deleterious effect on performance due to the simultaneous onset of the phenomenon of compressibility of air.

The Sound Barrier

Because a disturbance in free air is propogated at the speed of sound, the disturbance which a body creates by virtue of its motion is transmitted well ahead of it when the speed of motion is much slower than that of sound. However, if the body is moving at or faster than sonic speed then the disturbance that it creates cannot be propogated ahead of it.

Consequently, as aircraft speeds approached that of sound a sharp increase in aerodynamic drag resulted—because of the inadequacy of the prevailing state of knowledge of the practical behaviour of aerodynamic wing shapes in relation to this hitherto academic phenomenon. Hence the coining of the then popular term: 'Sound Barrier'.

Overcome by the twin technical innovations of the swept wing and the turbine engine—both invented in the 1930s and greatly exploited from the mid-1940s onwards—this so-called barrier proved to be merely a transient to be avoided rather than an impassable obstacle to further speed progress.

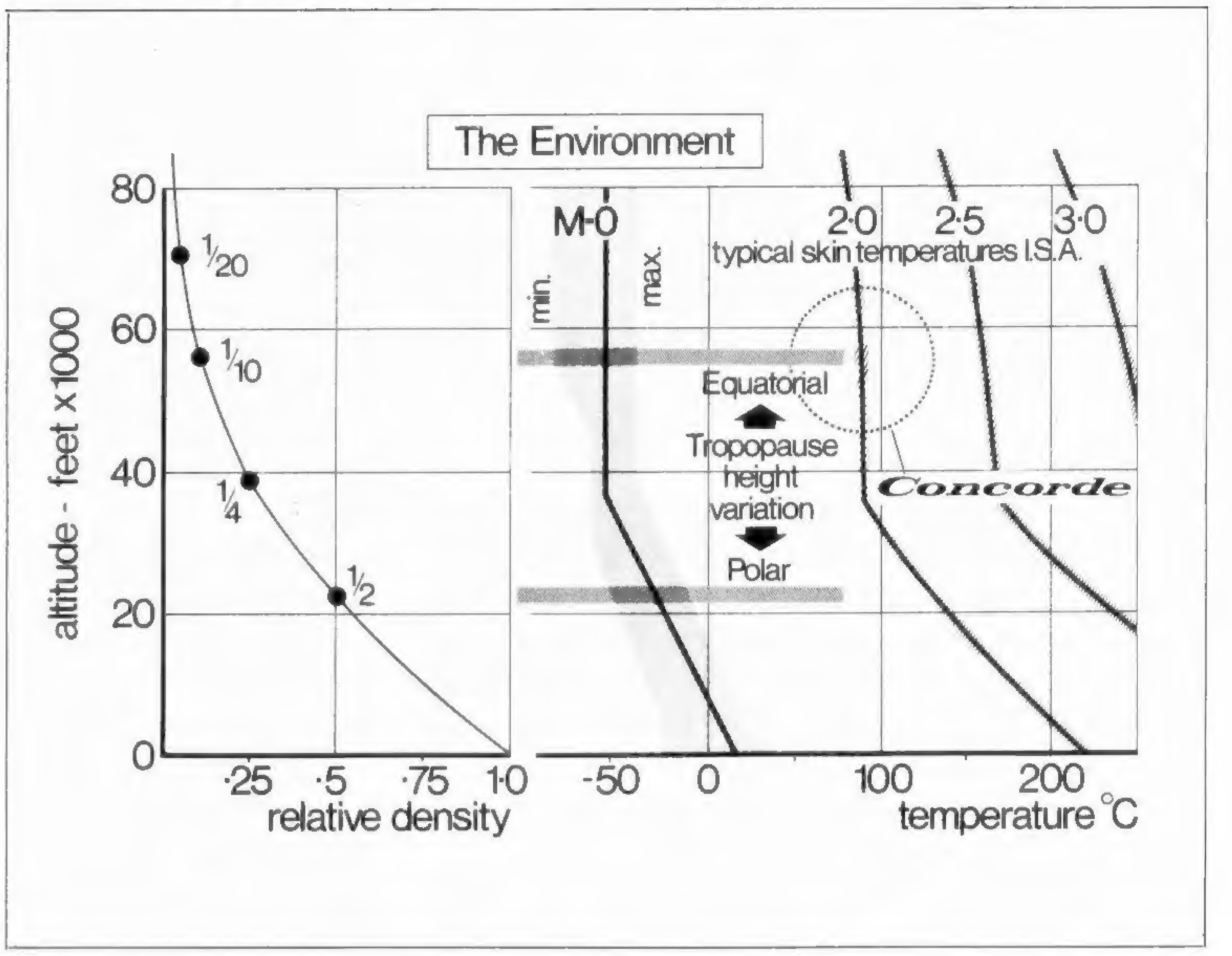
The supersonic regime of flight was opened up in the 1950s through the prevailing imperatives of military technology—from which was to stem the essential technical stimulus for the conception of the SST and ultimately the twice-the-speed-of-sound Concorde.

The 'Mach Number'

The concept of a ratio between the speed of motion of a body and that of sound was first defined by Ernst Mach (1838–1916), an eminent Austrian Professor of Physics. This ratio was used for a long time in scientific literature before the designation 'Mach Number' was coined by Jacob Ackeret, the noted Swiss aerodynamicist.

Mach Number is now widely used in the aerospace business as a convenient means of expressing the speed of an aircraft in relation to that of sound—the datum being unity when the aircraft is travelling at exactly the ambient speed of sound i.e. the sonic speed at the prevailing altitude and temperature conditions—to which it is proportional.

In 'International Standard Atmosphere' (ISA) conditions the speed of sound is approximately 762 m.p.h. (1,226 km./h.) at sea level. With increasing altitude the temperature falls by 1.98 degrees Centigrade per thousand feet, resulting in a progressive decrease to 658 m.p.h. (1,059 km./h.) at around 36,000 ft. (10,972 m.) altitude—the beginning of the 'stratosphere'. Because the temperature remains constant above this height (at —56.5 degrees Centigrade) the speed of sound also remains constant—up to around 65,000 ft. (19,812 m.).



The physical characteristics of the International Standard Atmosphere—notably the variation of relative density, Mach Number and temperature with altitude, and (right) the added effect of kinetic heating at SST Mach Numbers. Overlaying this picture in practice are further variations due to climatic effects.

Thus Concorde's cruising speed—Mach 2—is around 1,300 m.p.h. (2,092 km./h.) at its cruising height band of 50,000 to 60,000 ft. (15,240 to 18,290 m.).

Evolution of the Bisonic Generation

The exploitation of supersonic flight in Britain dates back to a little-known British Government decision of 1943 when with commendable courage it issued Specification E.24/43 for an experimental transonic aircraft intended to reach 1,000 m.p.h. at 36,000 ft. (Mach 1.5). The outcome was the imaginative Miles M.52, a single-engine aircraft with a bullet-shaped cylindrical fuselage with a conical (jettisonable) nose section containing a pressurised cabin for the single pilot. The M.52 was 90 per cent complete in February 1946 when the project was cancelled in favour of a programme of telemetered transonic flights by air-launched models, ostensibly on the grounds of excessive risk to the human pilot.

Vickers at Weybridge (a predecessor of BAC) did much work on this subsequent approach and constructed a series of experimental pilotless transonic research models, powered by liquid fuel rocket motors, for release from de Havilland D.H.98 Mosquito aircraft at 40,000 ft.

Early Supersonic Research and Military Aircraft

Cancellation of the M.52 enabled America to take the lead in establishing supersonic flight experience—following the epic first-ever flight at supersonic speed (Mach 1.06) in level flight by Captain 'Chuck' Yeager in the Bell X-1 air-launched rocket-powered research prototype on October 14 1947. The Douglas D-558-2 Skyrocket became the first aircraft to exceed Mach 2 in February of the following year.

Nevertheless, the traditional inventiveness and ingenuity of the British and French continued undaunted.

The first British aircraft to exceed the speed of sound (under control) was the de Havilland D.H.108 ('Swallow') swept-wing tailless research aeroplane which reached 700 m.p.h. in a dive from 40,000 to 30,000 ft. on September 6 1948 —piloted by John Derry.

The Seeds of the Fifties

America's progressive programme of the early 1950s—spurred by the needs of the Korean War—soon disposed of the sound barrier and supersonic flight became routine, first in diving flight and eventually in level and climbing flight. By 1955 the USAF had the North American F-100 Super Sabre—the world's first combat aircraft capable of sustained supersonic speed in level flight—in squadron service.

In November 1956, Convair flew its B-58 Hustler Mach 2 delta-winged bomber—the first large supersonic aircraft—generated from its XF-92A experimental supersonic fighter (the first true delta-winged powered aircraft to fly) and its F-102 Delta Dagger and F-106 Delta Dart Mach 1.5 fighters.

Two years later the Lockheed F-104 Starfighter —the first operational Mach 2 fighter—had proved that careful matching of engine and intake design was compatible with operational service at twice the speed of sound.

Meanwhile in Britain, the P.1A of English Electric (another predecessor of BAC) exceeded Mach 1 on its third flight in August 1954. This was the prototype of what was to become the Lightning, Britain's first fighter to be designed for sustained Mach 2 performance and which became established in squadron service in 1960.

The contemporary Fairey Delta 2 experimental prototype went on to establish a World's Speed Record of 1,132 m.p.h. (1,882 km./h.) on March 10 1956 and, as noted later, was further adapted to become a key aerodynamic tool in the development of Concorde.

In France, Mach 1 was first exceeded in level flight in August 1954 by the diminutive S.F.E.C.M.A.S. 1402 Gerfaut 1A—which was France's first high-powered jet delta-winged aircraft to fly. This was followed by the Sud-Ouest Aviation S.O.9000 Trident I mixed power unit lightweight interceptor research aircraft in April 1955, and S.O. 9050 Trident II (which reached 2000 km./h. (1242 m.p.h.) in January 1957).

In 1956 the delta-winged S.E.212 'Durandal' reached Mach 1.5 on its first flight and two more French delta-winged prototypes, the Dassault Mirage III and the Nord 1500 Griffon, exceeded Mach 2 in level flight.

The Griffon has a particularly significant link with the first pilot of Concorde—on February 25 1959 André Turcat established an international speed record of 1,018 m.p.h. (1,638 km./h.) over a 100 km. closed circuit and in October that year reached Mach 2.19 (1,448 m.p.h.—2,330 km./h.) at 15,250 ft. (4,648 m.) and became the first European to exceed Mach 2.

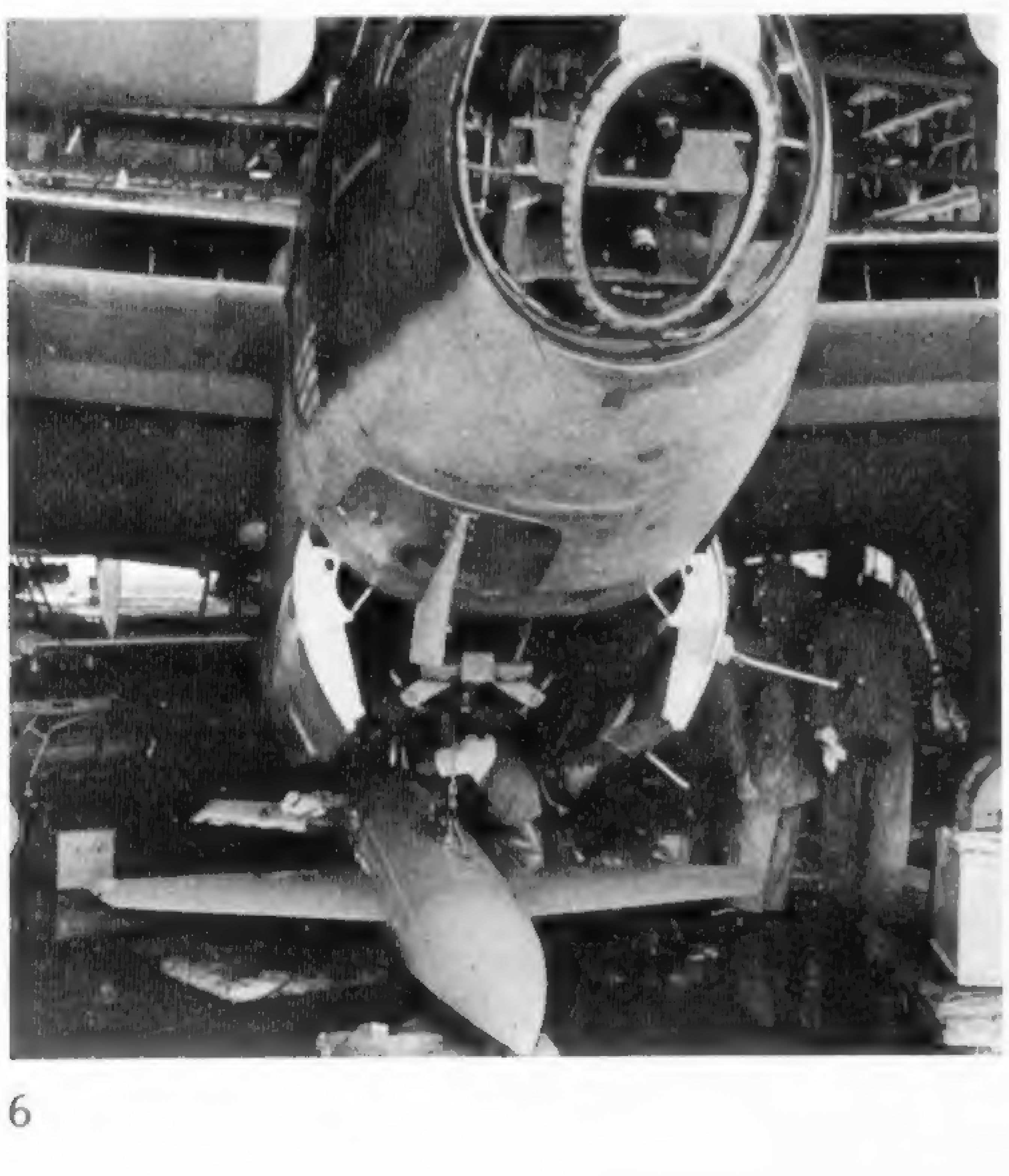
In 1957 the Dassault Super-Mystère B-2 became the first Western European aircraft to go into service as a genuine supersonic interceptor.

By the end of the 1950s it was clear that the problems of supersonic flight for military purposes had been fully conquered technically and Mach 2 flight was routine.

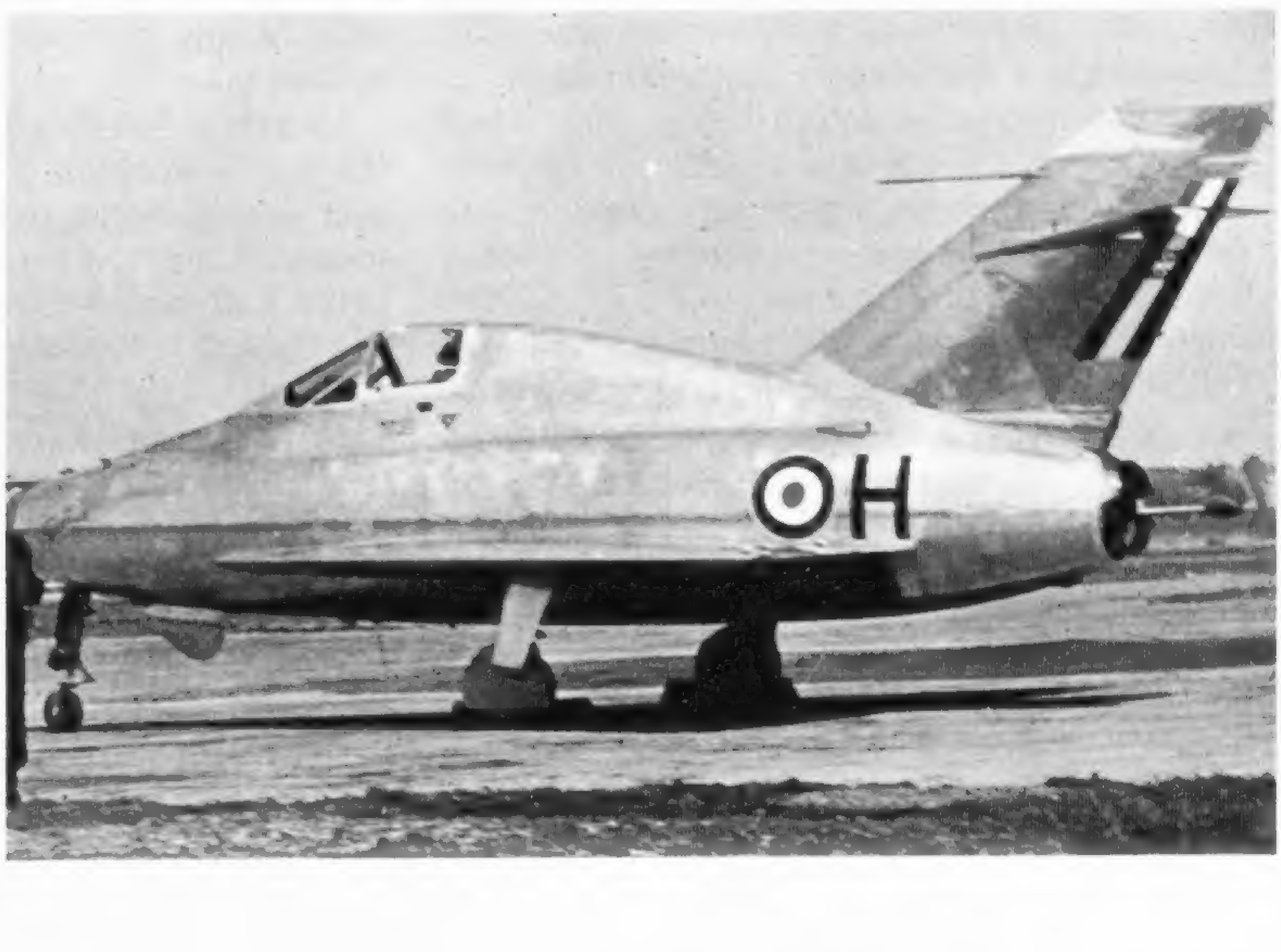
Advent of the SST

The lessons and the success of these research and military achievements fostered a growing appreciation of the commercial potential that could be derived from this significant new plateau of performance capability.

The dominant physical characteristic was the delta wing shape that had its origins in the pioneering research in Germany which was



Loading a rocket-powered air-launched scale model of the Miles M.52 under the fuselage of a Mosquito parent aircraft.



The Gerfaut 1A, France's first high-powered delta-winged aircraft to exceed Mach 1.0. (Photo: S. P. Blandin)

sequestrated by the Allies at the end of World War Two.

The potential improvements in the lift/drag ratios that could be achieved with the delta wing at supersonic speeds began to indicate that the operating costs of a supersonic airliner could be brought down to a commercially realistic level.

Pioneering British Milestone

A significant if unheralded event in the evolution of the practical SST was the formation in 1956 by by the British Government of the 'Supersonic Transport Advisory Committee' (STAC)—under the most able Chairmanship of Morien (now Sir Morien) Morgan, the eminent aerodynamicist—'to initiate and monitor a co-operative programme of aimed research designed to pave the way for a possible first generation of supersonic transport aircraft'.

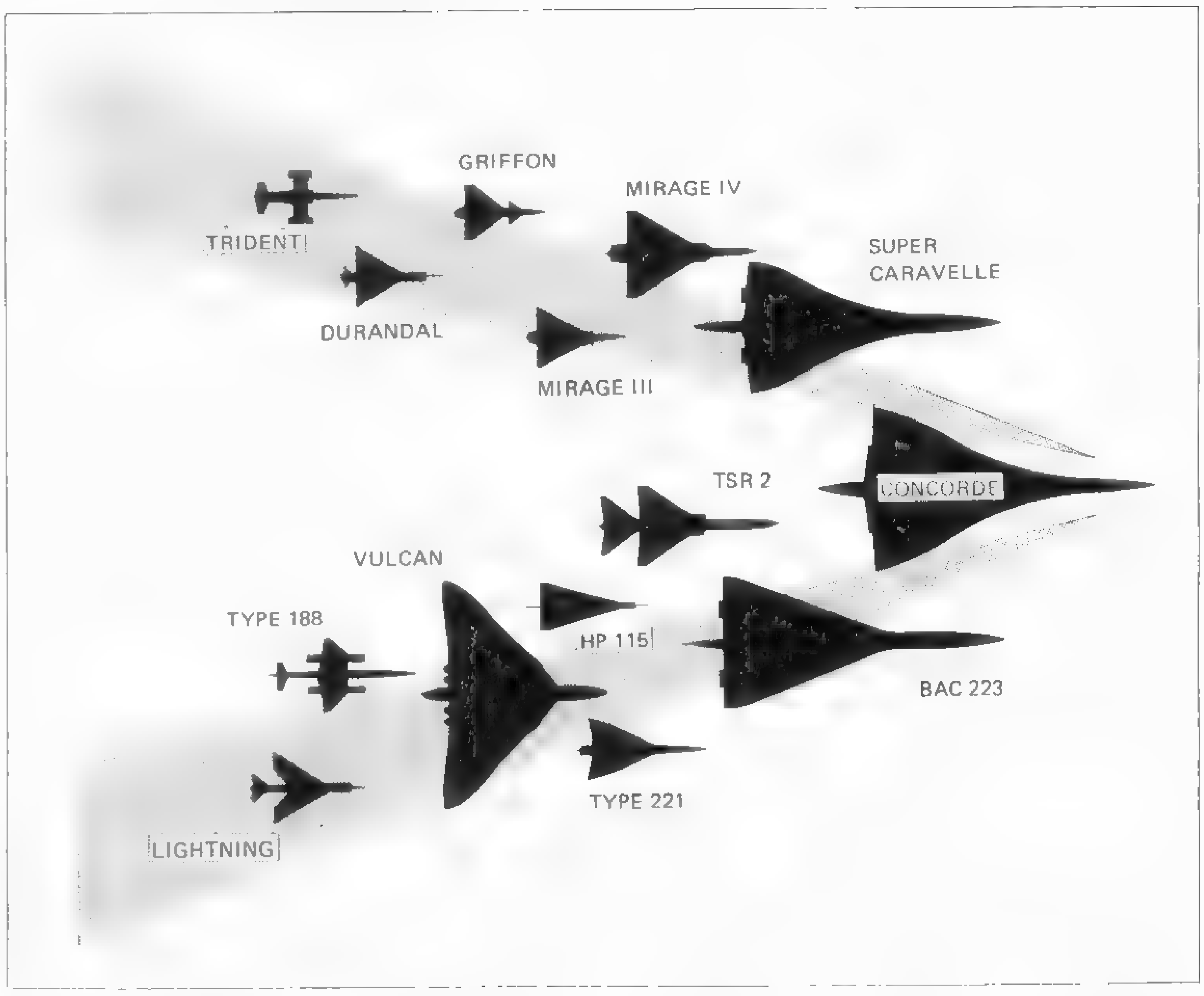
The 28-strong main Committee included representation from nine airframe companies—Avro, Armstrong Whitworth, Bristol, de Havilland, English Electric, Fairey, Handley Page, Shorts and Vickers; four engine companies—Armstrong-Siddeley, Bristol, de Havilland and Rolls-Royce; the national airlines—BOAC and BEA; the leading research establishments—RAE, NGTE and ARA; and the Air Registration Board (ARB), the Ministry of Transport and Civil Aviation, and the Ministry of Supply. It was supported by a 38-man technical sub-committee from these same organisations.

The first meeting of the STAC on November 5 1956 prefaced two years of quietly intensive research, costing over £700,000 and involving the production of more than 400 written contributions, to prove that the concept of a commercial supersonic aircraft was feasible. This work covered not only the primary technical disciplines of aerodynamics, structures, systems and propulsion but also operations, air traffic control, economics and the social effects of noise and the sonic boom.

Reporting its findings in March 9 1959, the STAC favoured two basic types—a medium-range (1,500 n.m.) aircraft cruising at Mach 1.2 and a long-range (3,000 n.m.) aircraft cruising at Mach 1.8.

Numerous feasibility studies were considered, employing a range of swept, compound-swept ('M' and 'W') and delta-wing planform shapes. All but the last were found suitable only for the lower speed. Theoretical and wind tunnel studies demonstrated that not only was the slender delta the best shape for Mach 1.8 but, contrary to earlier predictions, its overall suitability tended to improve up to and slightly beyond Mach 2.

The evolution of the characteristic slender ogival delta wing planform shape ultimately adopted for Concorde was probably the most significant result of the wide-ranging research and development work of the STAC.



The progression of British and French research and military aircraft from which the basic technology of Concorde stemmed.

To complement and extend the highly promising theoretical and wind tunnel research, which involved over 300 test models, the Ministry of Supply subsequently sponsored two research aircraft to explore the practical characteristics of this preferred shape.

For low-speed research, Specification X.197 materialised as the Handley Page H.P.115 first flown on August 17 1961. For both high and low-speed investigation of the refined ogival delta shape of Concorde, Specification ER.193D became the Bristol (BAC) 221—a conversion of the Fairey Delta 2—which was first flown at Filton on May 1 1964.

In order to decide whether to integrate the fuselage within a fairly thick wing profile or to adopt a discrete fuselage associated with a relatively thin wing, feasibility studies of the two shapes were commissioned from Hawker Siddeley Aviation and Bristol Aircraft respectively.

In the ultimate comparison the thin wing proposal was found to have a decisive advantage and a design study contract was awarded which resulted in the Bristol Type 198, a light-alloy mid-wing slender-delta with six Bristol-Siddeley 'Olympus' turbojets (already in production for Britain's 'V' bomber force) installed under the wings. This study was submitted in August 1961—together with a Mach 3 steel and titanium aircraft (the Bristol Type 213) for comparative purposes.

The Mach 2 Decision

The cost and development time needed for the Mach 3 study were found to be much greater than those for the Mach 2 design. While much was by then known about aircraft designed for speeds of Mach 2.0 nothing at all was known

about the Mach 3.0 regime.

As Sir George Edwards said later: 'This may be an old-fashioned reason for choosing Mach 2.0 but those responsible for the success of a great undertaking are always likely to be less adventurous than the enthusiastic supporter.'

Efficiency

Close study of vehicle efficiency, together with the properties of structural materials at the greatly elevated temperatures engendered by the kinetic heating phenomenon due to the friction of the air passing over the surface of the aircraft at these high flight speeds—a completely new factor in commercial airliner design and operation—amply verified this almost intuitive judgement.

Overall aircraft efficiency is essentially a function of the lift/drag (L/D) ratio of the aircraft and the propulsive efficiency of the engine.

Typically around 16 for todays jets cruising at Mach 0.8, the L/D ratio falls sharply to around 9 in the transonic region and then moves slowly to between 7.5 and 7.0 in the Mach 2.0 to Mach 3.0 speed band. Fortuitously the thermal efficiency of jet engines increases steadily from around 25 per cent at todays subsonic cruise speeds to around 40 per cent between Mach 2.0 and 3.0.

Combining these two factors to determine the overall vehicle efficiency showed that much of what was lost in the transonic region was recovered by the time Mach 2.0 was reached, indicating that between Mach 2.0 and Mach 3.0 it should be possible from aerodynamic and thermodynamic considerations to produce a vehicle with efficiency close to that of subsonic jets. Hence attention was closely focussed on this range of speeds.

Materials

On the question of airframe materials, whereas at subsonic speeds the structural temperature during cruising flight is of the order of minus 35°C, at Mach 2.0 the kinetic heating effect raises this temperature to around 120°C; at higher speeds it continues to rise rapidly—roughly as the square of the flight speed—so that at Mach 3.0 it has more than doubled again to 250°C.

While 120°C could still be tolerated by available aluminium alloys, the substantially higher temperatures at Mach 2.5 to 3.0 would have demanded exclusive use of steel and titanium.

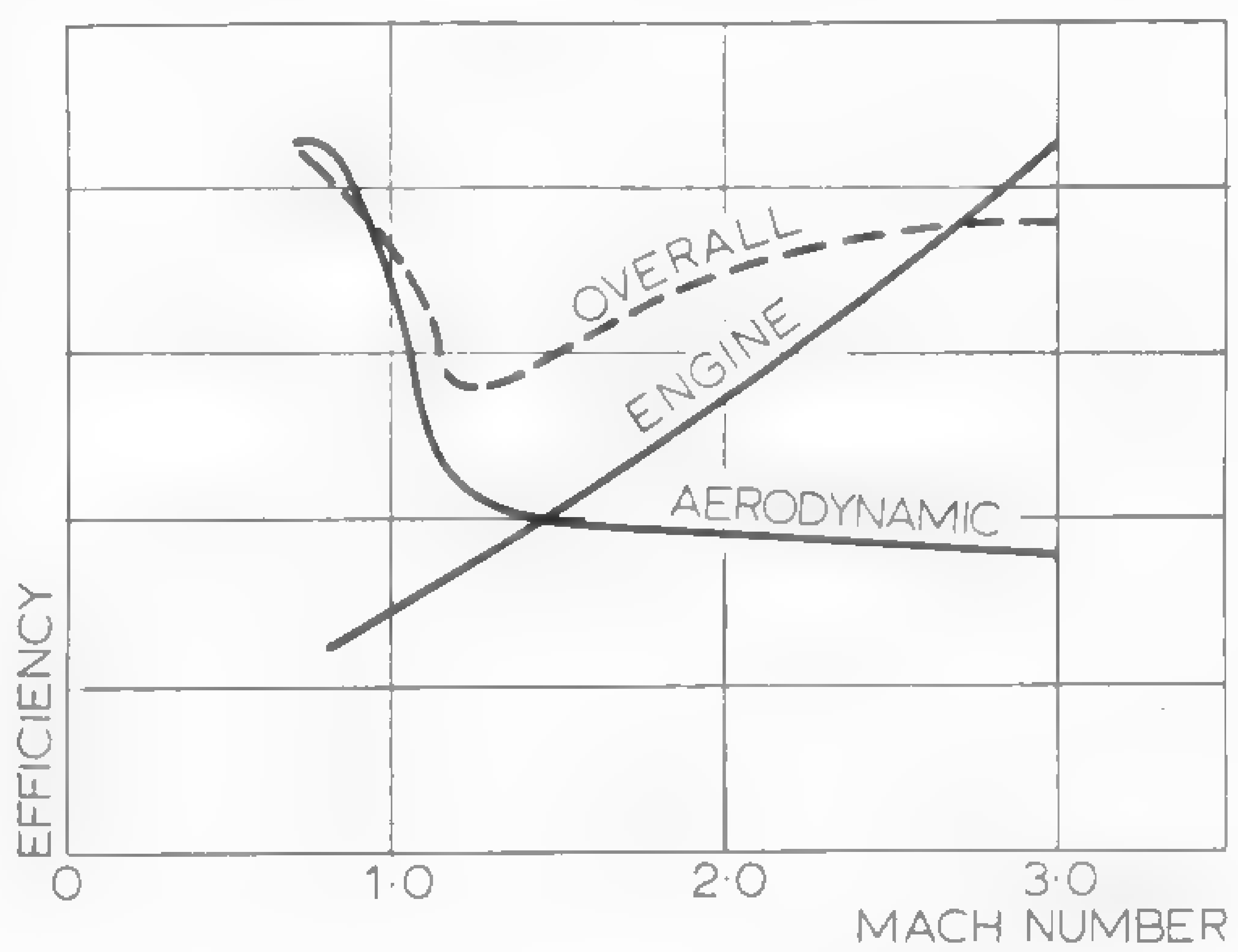
Apart from the much higher cost and more difficult fabrication techniques required, these largely untried materials are so strong that relatively small thicknesses are required to carry the loads encountered and hence further weight has to be expended in stabilising the structure against buckling. This means that the resulting structures are even heavier and more expensive.

In addition to the choice of materials, the kinetic heating effect also influences the design of the systems.

Weight and complexity—and hence cost—increase sharply in both areas with increasing design temperature. When it is appreciated that the payload fraction of an SST is only about one-twentieth of the fully laden weight, the paramount importance of weight-saving and avoidance of complexity are obvious.

Moreover, the massive extra outlay that would have been involved in the higher speed design would still have only reduced the transatlantic journey time by around 30 minutes —from 3½ to 3 hours—whereas the entirely feasible Mach 2 design would *halve* today's 7 hour journey time.

All these factors pointed to a cruise speed of Mach 2.0 for a practical long-range SST. Below this speed, overall vehicle efficiencies tended to be too low and above it the additional weight, cost and complexity combined completely to invalidate economic viability within the prevailing state of knowledge.



The variation of vehicle efficiency with Mach Number.

The extreme difficulties encountered with the all-steel Bristol Type 188 (built to Specification ER.134 for research into flight problems in excess of 1,500 m.p.h. and first flown on April 14 1962) were clear vindication of the ultimate decision of the British and French.

The insurmountable problems of the ill-fated North American B-70 Valkyrie Mach 3 experimental steel bomber (the first large long-range supersonic aircraft—first flown in 1964) and the stillborn American Mach 3 SST design of the late 1960s (cancelled in 1971) were yet further convincing evidence that this was the right course to follow.

Conception of the Anglo-French SST

It was a condition of the Bristol design study contract that the possibilities of co-operation should be explored with manufacturers in the USA, Germany and France. Whereas the Americans were convinced that an SST based on their experience with the B-70 should be their objective, and Germany was not willing to

participate, the 'state of the supersonic art' in France was well advanced and the opportunity of collaboration was welcomed.

French experience with the Dassault Mirage III and IV fighters together with the commercial success of the pioneering Sud-Aviation Caravelle rear-engined subsonic regional jetliner, had also led (quite independently of the British work) to the choice of a cruising speed of Mach 2.0 for an SST.

Meanwhile, sonic boom studies (and the adverse economics of six engines) had shown that the Bristol 198 was too heavy to be acceptable in this respect. Consequently, in 1961 the Bristol design team, led by Dr. Archibald Russell and Dr. William Strang, submitted a new and smaller project, the Bristol Type 223 with four Olympus engines.

Significantly there was a remarkable similarity between this new design and the latest French SST study evolved by the Sud-Aviation team under Pierre Satre and Lucien Servanty—the 'Super Caravelle' which was unexpectedly revealed at the Paris Air Show in 1961.

Closer co-operation between British Aircraft Corporation (formed the previous year by a merger of the aviation interests of Bristol, English Electric and Vickers) and Sud-Aviation of France was agreed in mid-1961—to study pooling of resources and the possibility of adopting a single design.

The first joint BAC/Sud meetings were held in Paris on June 8 1961 and at Weybridge on July 10 1961. Formal agreement came 16 months later—after technical agreement had been reached on a joint design, resources in Britain and France discussed and responsibilities defined, and a full report made on all aspects of the proposals to the respective Ministers.

Historic Agreement—the Beginning of Concorde

What was to become one of the most outstanding international political and industrial treaties ever was the:

'Agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of the French Republic regarding the development and production of a civil supersonic transport aircraft'

which was signed at Lancaster House in London on November 29 1962—by Mr. Julian Amery, the British Minister of Aviation and M. Geoffroy de Courcel, the French Ambassador to Britain.

From this impressively brief and simple agreement (with no cancellation clause) stemmed an international technical and industrial enterprise that was unprecedented in the field of commercial aviation.

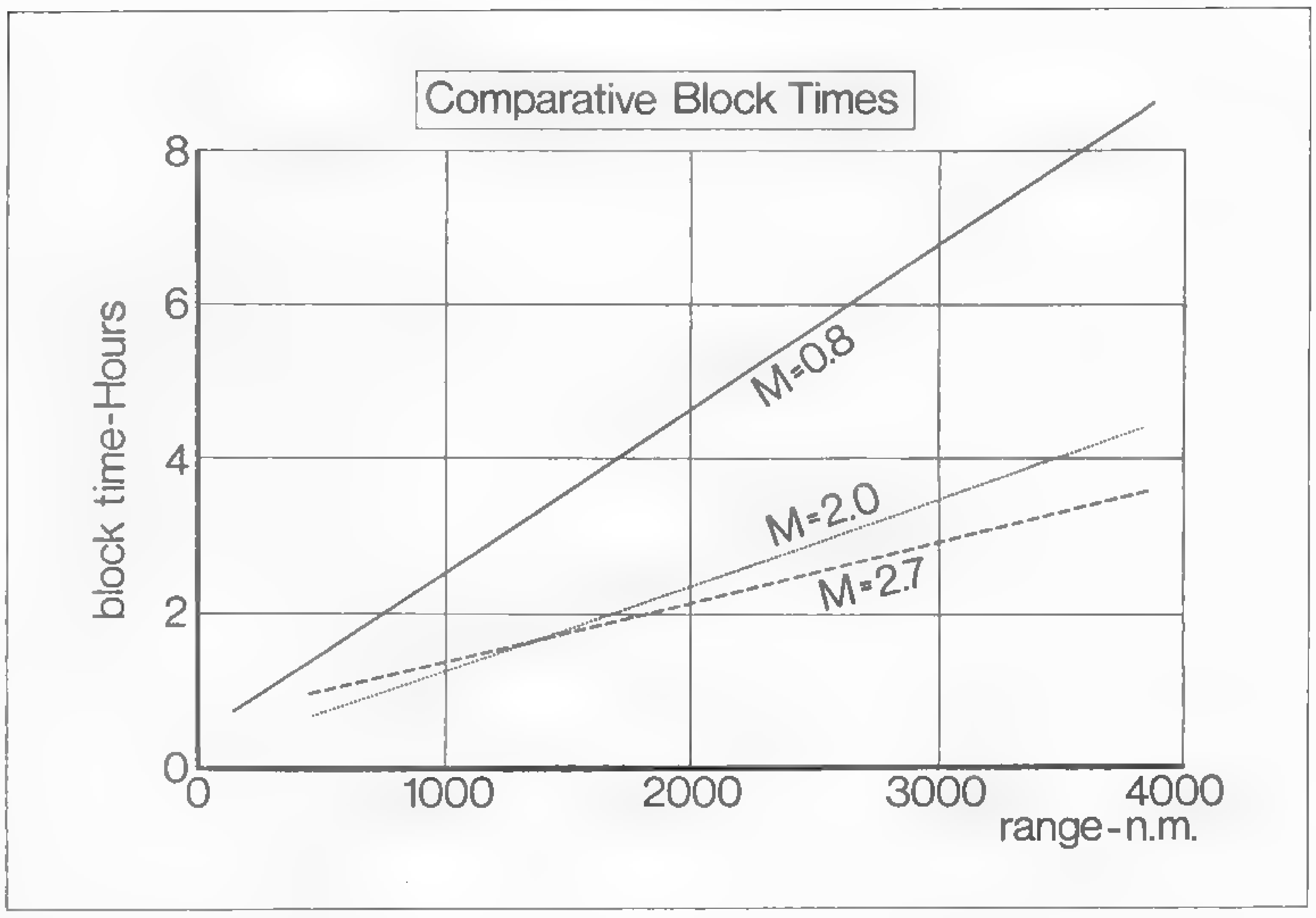
Concorde thus became not only the first major international collaborative venture in advanced technology to be started in Europe but also the largest and most complex industrial programme ever to be undertaken by two nations in peacetime.

British Aircraft Corporation in the UK and Sud-Aviation in France (that is today part of Société Nationale Industrielle Aérospatiale—SNIAS) were charged with the responsibility for the airframe and Bristol Siddeley (that is today part of Rolls-Royce) of the UK and Société Nationale d'Étude et de Construction de Moteurs d'Aviation (SNECMA) of France were to be responsible for the powerplant.

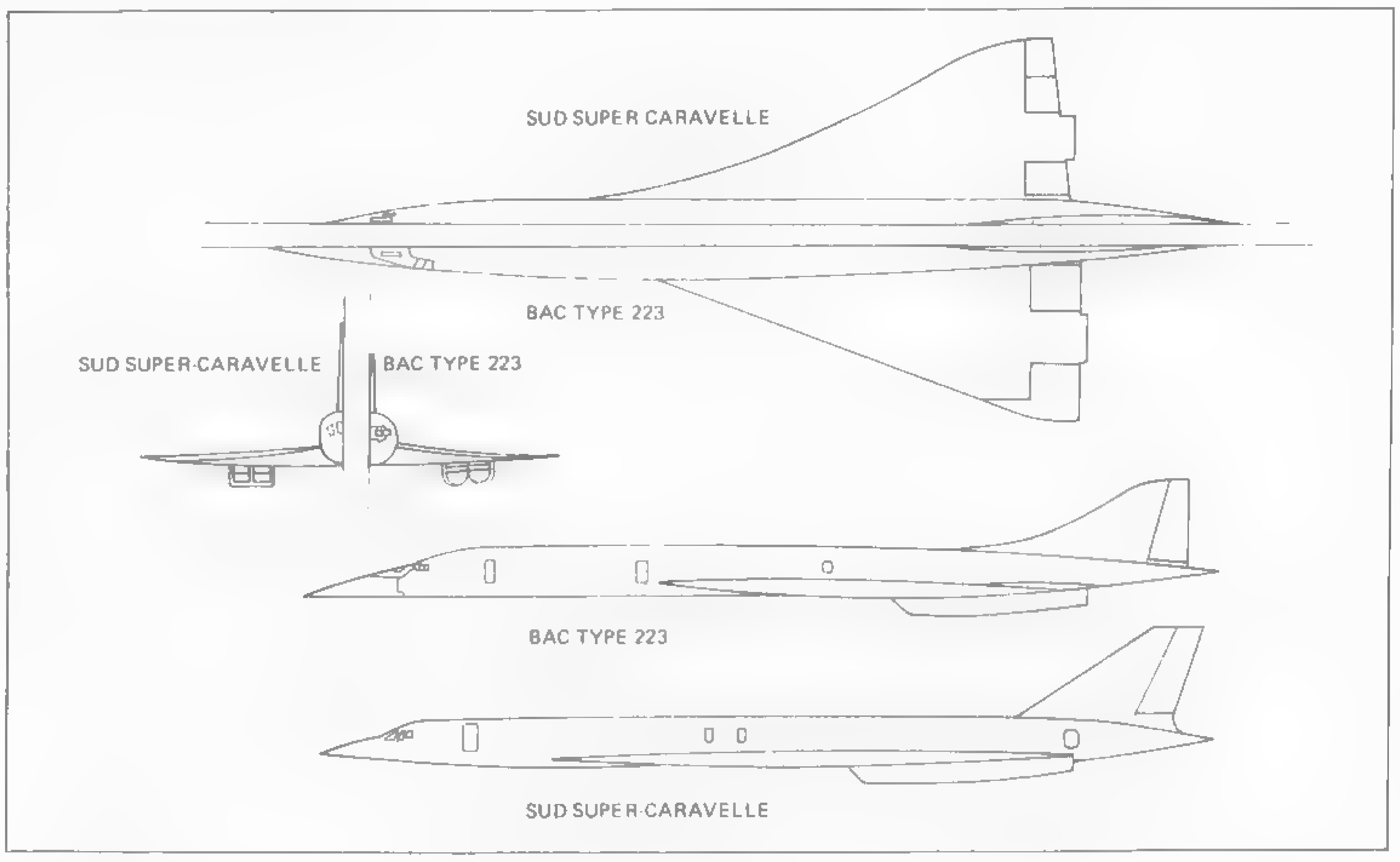
The Significance of a Name

Soon afterwards the eminently appropriate name 'Concorde' was suggested by 18-year-old Timothy Clark, son of Mr. F. G. Clark, Sales Publicity Manager of the BAC Filton Division, and officially adopted by both Governments.

However, it was to take another five years before the spelling of the name—with a final 'e' as in French or without as in English—was clarified. A gracious solution was reached on December 11 1967 when the first Concorde prototype (001) was ceremoniously rolled out at the Sud factory at Toulouse in France. Mr. Anthony Wedgwood Benn, British Minister of



Comparative journey block times with aircraft design cruising speeds.



Comparison (showing remarkable similarity) of the Sud-Aviation 'Super-Caravelle' and the BAC 223 SST designs that preceded the definitive Aérospatiale/BAC Concorde.

Technology, concluded his speech on that occasion with appropriate humour: 'Only one disagreement has occurred during the years of co-operation with France. We were never able to agree on the right way to spell 'Concorde'—with or without an "e". I consider this situation to be unbearable and I have decided to solve the problem myself. The British "Concorde" shall from now on also be written with an "e" for this letter is full of significance: it means "Excellence", "England", "Europe", and "Entente".' 'This is a symbol of the friendliness and understanding which links our two countries', he said.

Symbolic of excellence, 'Concorde' was soon adopted as a brand name for a wide range of products and business enterprises in many countries.




Sir Archibald Russell.

Dr. William Strang.

M. Pierre Satre.

M. Lucien Servanty.

Anatomy of a Classic Shape

At this point it is appropriate to review the development of the characteristic shape of Concorde, the choice of engine and powerplant installation, and of airframe materials.

Wing Design

The primary objective in the design of the Concorde wing was the achievement of maximum aerodynamic efficiency consistent with the conflicting requirements of high and low speed flight. Hence the ultimate configuration had to be a compromise, but largely determined by the design Mach number. The higher the Mach number, the higher the angle of sweepback required, and because of the spanwise drift of the boundary layer, the aspect ratio had to be kept small to prevent a large build-up at the wing tip.

In considering the ideal planform for supersonic flight the point is reached where it is possible to lengthen the root chord of a highly swept wing and straighten the trailing edge for lateral and pitch control placement and thus eliminate the need for a horizontal stabiliser. The result is the 'delta' planform.

A major advantage of this shape is that the greatly lengthened root chord means that the enclosed volume of the wing and hence the fuel capacity are considerably increased for a given thickness/chord ratio. The large root chord also means that the delta wing can overcome all the disadvantages of lack of structural stiffness and lack of wing volume associated with thin, highly swept wings, and yet remain aerodynamically thin.

The sudden drop in lift/drag (L/D) ratio that occurred at around Mach 1.0, as mentioned earlier, was associated with a rearward shift of centre of lift. Experience at speeds beyond Mach 1.2 showed that the fore and aft control problem could be solved by provision of adequate trimming and that the rapid fall in L/D in the transonic regime is checked at around Mach 1.15 and thereafter decreases quite gradually if a suitable delta shape was chosen. The optimum theoretical shape for cruise performance for Mach 2.0 was found to be a slender delta about three times as long as its semi-span with slenderness increasing for higher speeds—more slender shapes having completely unacceptable handling characteristics at low speed.

For the Concorde mission the simple 'triangle' had unsatisfactory characteristics at low speed and also required further development to meet a number of conflicting requirements implicit in that mission which can be broadly summarised in four main respects: supersonic wave drag—due to lift and volume—minimised by the use of large wing chord; vortex drag—at all speeds—minimised by the use of large wingspan; skin friction drag and wing structure weight—each minimised by scrupulous adherence to close tolerance engineering and assembly standards; and kinetic heating which, as already explained, is a direct function of the design cruising speed.

Satisfying these conflicting requirements led to the development of the now familiar 'Ogee', (or 'Wine Glass') wing planform shape for Concorde and it was found possible to achieve the required L/D, with a moderately long fuselage nose.

At the same time a position for the centre of gravity could be obtained with realistic location of payload and fuel—which had to be forward of the subsonic aerodynamic centre in low speed flight and coincident with the centre of lift in supersonic cruise. It was found that the distance between these centres could be substantially reduced by suitably shaping the triangle to a curved ogival shape, with increased sweepback at the root and tip. By using curved 'streamwise' tips and extending the root fillets forward it was found possible to ensure attachment of the leading edge vortex sheet—which is

formed naturally on this type of wing—right down to and below the 'stall'.

The resulting wing has a very important additional aerodynamic characteristic in that it does not have a stall in the generally accepted sense; the development of these vortices means that the stall angle is so large that it is impossible to reach a stalled condition in any reasonable condition of flight. At minimum control speed the attached vortex increases lift by as much as 30 per cent in free air and twice as much in the ground cushion. It thus acts as a 'variable area wing' without the attendant problems of a mechanical system—other than the need for an automatic throttle control to cope with speed instability.

The flow development is smooth with increase in incidence and so is the lift and pitching moment. The flow also changes smoothly with Mach number. There are therefore no abrupt changes in aerodynamic characteristics through the operating range of incidence and Mach number.

Because of the considerable rearward shift of aerodynamic centre of pressure as the aircraft passes through the transonic acceleration phase, substantial retrimming of the aircraft becomes necessary.

This is achieved on Concorde by the unique feature of transferring fuel from a group of tanks forward of the centre of gravity (CG) to a tank in the rear fuselage. After supersonic cruise, the fuel is transferred forward again to restore the subsonic CG position. By using fuel transfer to maintain the trim of the aircraft there is no penalty in extra drag which would be involved if aerodynamic means had been used. All the trim fuel is usable, being part of the total fuel load.

In the necessity to optimise the fuel load—taking into account both supersonic and subsonic performance—the low speed regime is especially significant in the Concorde mission. Fortuitously the final shape of the aircraft has also resulted in a pattern of holding and approach performance that is comparable to current subsonic jets. Hence, as its now extensive route flying has shown, Concorde can be readily integrated with existing air traffic control and airport procedures.

In summary, the ultimate design of the Concorde wing has resulted in an excellent compromise between good low-speed controllability, high supersonic cruise efficiency and optimum overall efficiency, since, as predicted, the increase in drag from around Mach 1.5 up to Mach 2.0 has been more than balanced by the steady increase in propulsive efficiency of the Olympus engine.

Fuselage

The technical demands of the operating domain of Concorde have also resulted in a slim and sleek payload carrier. Since frontal area is very expensive in terms of supersonic drag, the fuselage cross-section is a minimum consistent with an optimum standard of four-abreast seating.

Sized to provide a natural growth in productivity compared to first generation intercontinental jets, Concorde will carry between 108 and 144 passengers.

The external temperature of the fuselage skin at cruise of around 120°C has to be reduced to around 20°C inside the passenger cabin within the space of only 5 in. (12.7 cm.). This is a completely new problem in commercial airliner design.

Because Concorde cruises $1\frac{1}{2}$ times as high as today's intercontinental jets, a maximum cabin working differential pressure of 10.7 lb./sq. in. (0.75 kg./sq. cm.) is necessary.

While these factors accentuate the physical problems of the design of the interior, as stated earlier, the drastically reduced journey times effectively equate Concorde operation to that of a short-haul jet. However, this has not resulted in any relaxation in comfort or environmental standards.

Despite the severe technical and operational restraints and the inability fully to exploit 'sculpturing' techniques, the experienced BAC/Charles Butler partnership has evolved a most attractive and space-efficient interior concept to match the imaginative new marketing concepts discussed later.

All delta wing aircraft have a relatively high angle of incidence at slow speeds, including approach and landing. Improvement of pilot visibility for Concorde is achieved by moving the nose downwards and by lowering the transparent visor—another completely new requirement for a commercial aircraft. For landing, the nose is in the fully drooped position (−15°) and for taxi-ing and take-off it is in the intermediate (−5°) drooped position. The visor is fully raised for high speed flight to give a clean aerodynamic shape by covering and hence fairing off the windshields. It also protects the windshield from the effects of kinetic heating.

The Propulsion System

The choice of engines for Concorde was also the end-product of many conflicting requirements. Essentially these were that it should have a high specific thrust for take-off, transonic acceleration and supersonic cruise, together with low fuel consumption in both supersonic and subsonic conditions. A very high pressure-ratio turbojet would have given a low power-plant weight but would have resulted in an excessive turbine entry temperature. A high by-pass ratio engine could have shown improved fuel consumption but with its lower specific thrust would have required a heavier overall powerplant installation and its large diameter would also have meant a high momentum drag; the weight penalty more than offset the weight of fuel saved.

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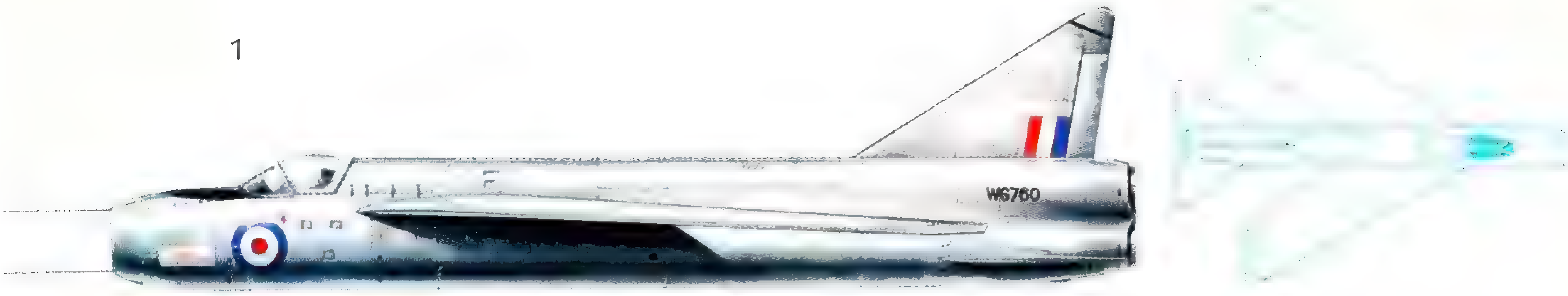

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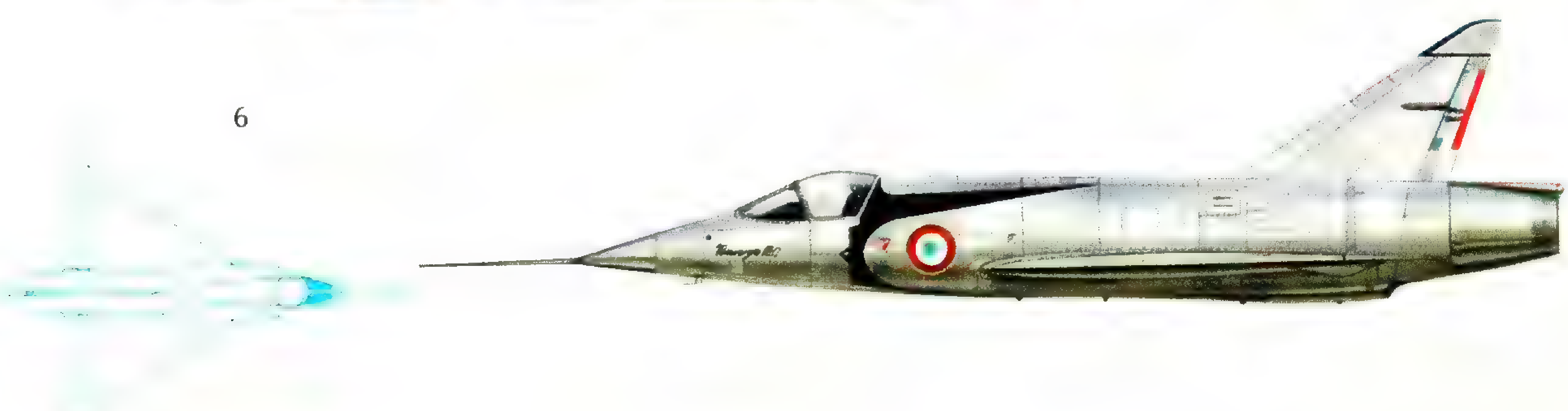


Terry Hadler/David Palmer

Consequently a moderate pressure-ratio turbojet with a cooled turbine was chosen because at supersonic speeds a substantial compression occurs in the nacelle intake and therefore the pressure ratio required from the engine itself is much lower.

Such an engine could be made available in the required size by development of the Bristol 'Olympus' military turbojet that was already in production for the BAC TSR.2 supersonic bomber.

The commercial version of this engine—the Olympus 593—with a compressor pressure ratio of 11.3:1 at the design cruise condition of Mach 2 at 60,000 ft. ISA + 5°C, combined with a small frontal area and low overall powerplant weight, has proved to be an excellent choice for Concorde. Nevertheless it has been a major development. Its thrust was increased partly by modifying the compressors and partly by using the high turbine entry temperature permitted by the cooled turbine essential for sustained cruising at supersonic speeds.

The location of Concorde's powerplant under the wing ensured that the intakes were in a region of minimum-thickness boundary layer and favourable pressure fields, and changes in intake flow direction during take-off and final approach were minimised. Additionally, it made for ready accessibility for servicing.

Due to the wide speed range the intake/exhaust systems have to be carefully matched to the engine. To meet the engine air demands, variable area intakes are required to enable the engine compressor inlet to be presented with a subsonic airflow and to ensure maximum pressure recovery at all flight speeds. Thus the engines are arranged in pairs in rectangular cross-section nacelles giving substantially two-dimensional flow in the intake ducts, and to simplify mechanical control of the variable geometry intake.

The convergent/divergent intake duct is formed by means of moveable ramps in the roof of the intake and a spill door, incorporating intake flaps, in the floor of the intake. The front ramp causes the formation of a shock-system to reduce the speed of the inlet air to just below the speed of sound. The air is further decelerated in the divergent duct formed by the rear ramp. During take-off the ramps are fully raised and the flaps in the spill door automatically open inwards to provide maximum air flow to the engine. At speeds above Mach 1.3 the ramps start to lower automatically to control the position of the shock waves and achieve the required reduction of air velocity at the engine face. During Mach 2.0 cruise, conditions at the compressor inlet are Mach 0.45 and pressure equivalent to about seven times ambient.

A variable convergent/divergent exhaust system is also essential for thrust and performance optimisation at all conditions, and a reheat system is used to provide thrust boost at take-off and during transonic acceleration.

The exhaust assembly—incorporating the latest system known as the TRA (Thrust Reverser Aft) or Type 28 nozzle—comprises a variable area primary nozzle, the TRA feature which is a combined secondary nozzle with reverser buckets, and retractable 'spade' type silencers. This assembly forms a monobloc structure for each pair of engines. The two 'clamshell buckets' at the rear of the unit perform the dual function of variable secondary nozzle and thrust reverser. Apertures in the upper and lower surfaces allow exit of the deflected exhaust gas during reverse operation and inward passage of tertiary air to control exhaust gas expansion during flight.

The TRA is also used to reduce airport noise by the action of the secondary nozzle on the exhaust jet stream. 'Fish Tailing', or squashing, the jet at take-off reduces significantly the side-line noise level. This system also incorporates eight equi-spaced retractable spade silencers, housed in the main body of the secondary exhaust assembly, which are deployed to reduce community noise during the fly-over phase.

The Olympus 593 Mk.602—the production standard engine—is a substantial improvement over earlier variants, with greater thrust and lower fuel consumption. Its new-design pre-vaporisation type annular combustor virtually eliminates all smoke emission by ensuring more complete combustion of the fuel/oxidant mixture.

By the time the Olympus 593 is introduced into airline service it will have undergone one of the most extensive development programmes ever and will have logged more than 35,000 bench and flight hours—including an initial programme of airborne testing in a complete nacelle unit mounted under a Vulcan bomber testbed aircraft.

The Thermal Problem and Materials

For reasons already discussed, the primary airframe constructional material for Concorde is aluminium alloy.

The under-wing variable-geometry engine air intake section monobloc for two of Concorde's Olympus engines on one side of the aircraft.

Contributing to Concorde technology **(see also page 29)**

1 English Electric (now BAC) P.1 *(serial WG760); August 1954.*

2 Fairey Delta 2 *(WG774); October 1954.*

3 Sud-Ouest S.O. 9050 Trident II *('T'); July 1955.*

4 Nord-SFECMAS 1502 Griffon *('I'); September 1955.*

5 Sud-Est S.E.212 Durandal *('D'); April 1956.*

6 Dassault Mirage IIIC; *October 1960.*

However, the thermal problem is a complex one. Because the creep-resistance of this material falls rapidly with increasing temperature the strongest types were not suitable. Hence it was decided to adopt the more conservative aluminium/copper alloys of a type long used for engine components—since become known as 'Hiduminium RR 58' in Britain and 'AU2GN' in France.

Hitherto these alloys had been employed mainly as forgings but they have since been made available as sheet and plate in the sizes required for Concorde. Very substantial fatigue and sustained-load tests on these materials at elevated temperatures have been in progress since 1962 and Concordes makers are satisfied that they are completely safe and satisfactory within the aircraft flight envelope.

In addition to these considerations of basic material choice, exceptional care has been taken in the structural design process to take account of thermal stresses.

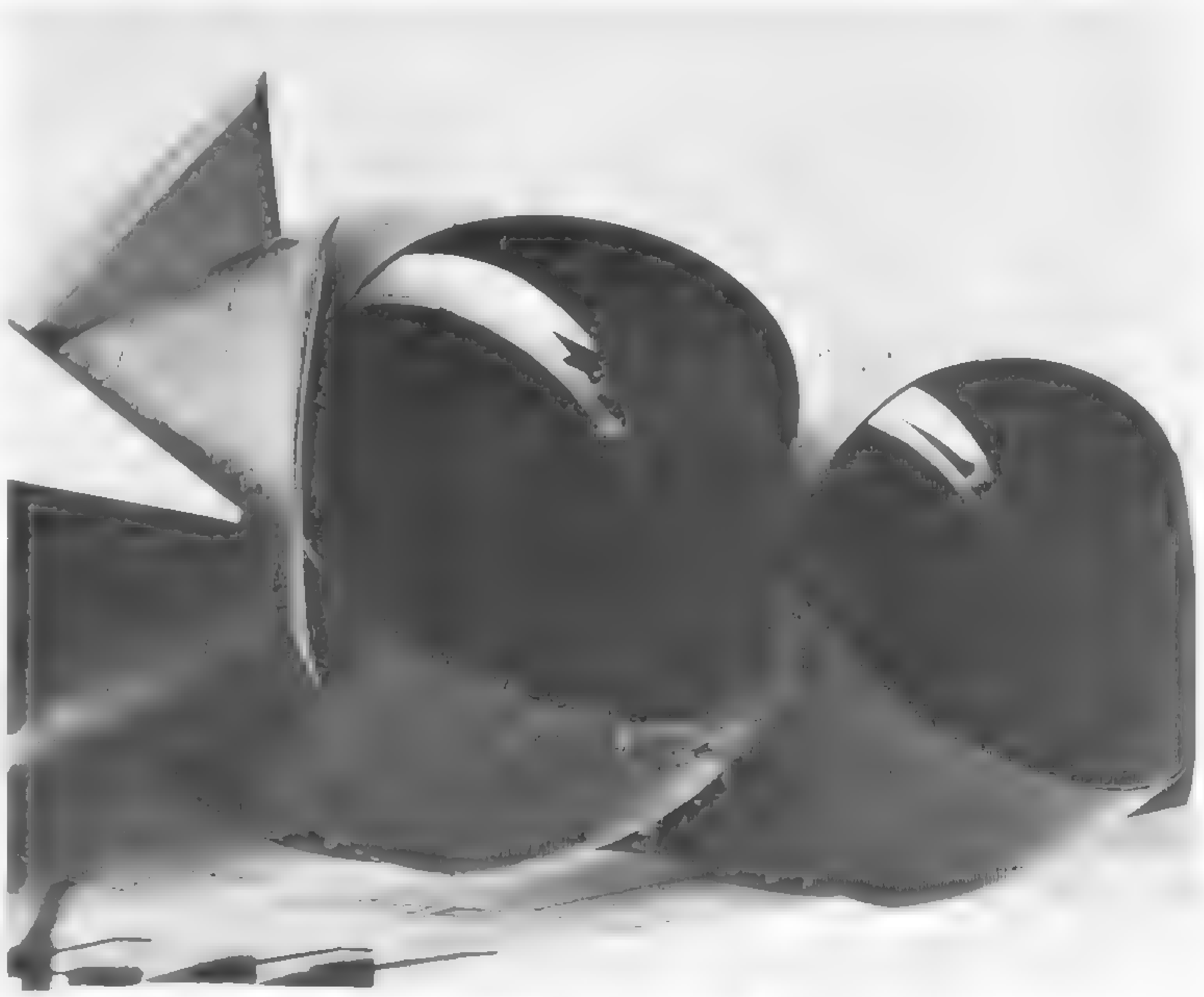
While the external skin temperature of Concorde's wing is raised to around 120°C at supersonic cruise, the internal structure only picks up heat by conduction, thus putting the skin into compression and the internal structure into tension. Special provisions, such as pin-jointed attachments and fluted webs, are used to relieve the resultant strains.

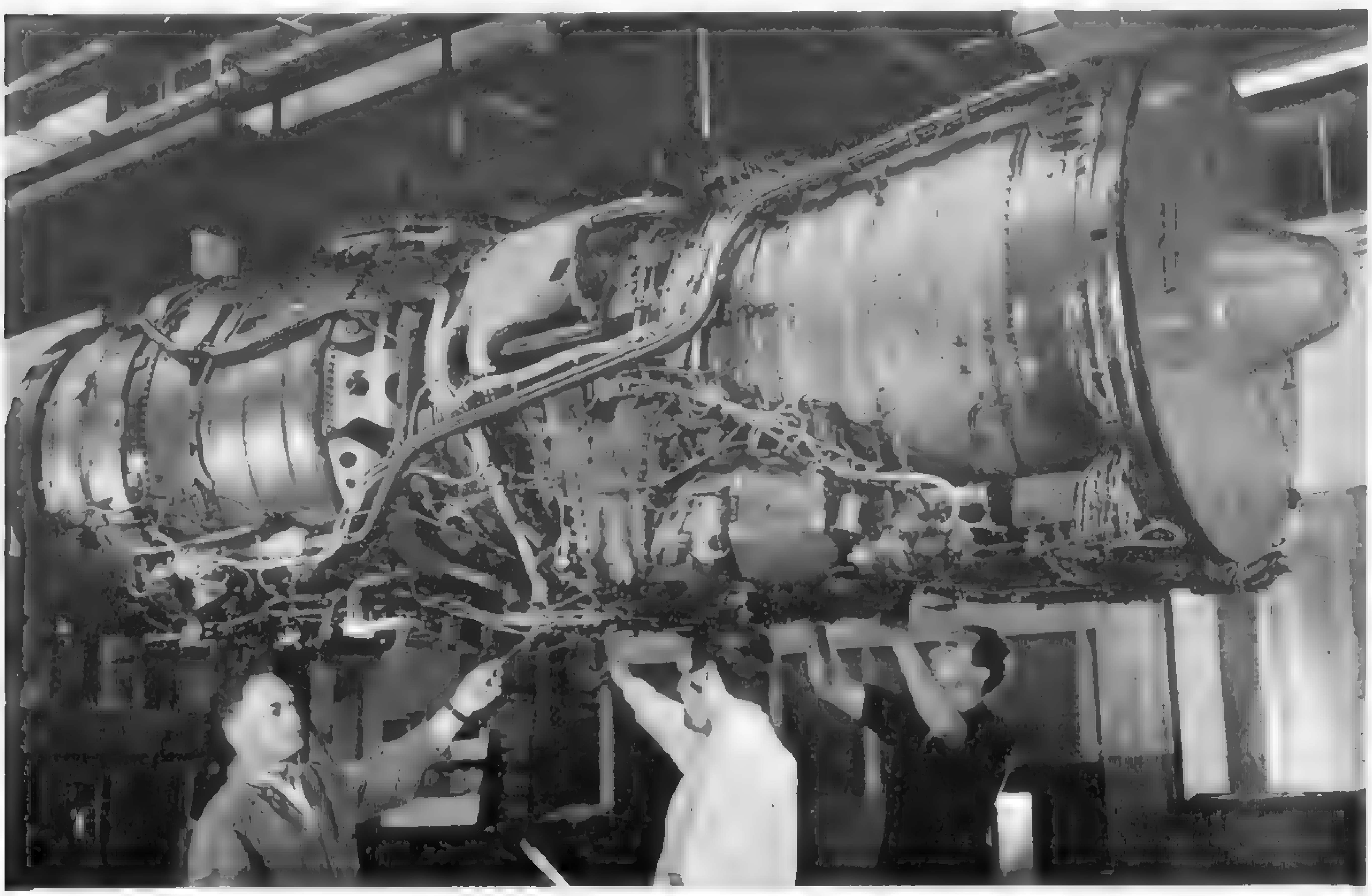
All these problems of thermal fatigue are being studied by carefully simulated tests in which a complete Concorde airframe, located in a major new thermal test facility at the RAE Farnborough, is being subjected to alternate heating and cooling cycles to represent flight conditions. This complements the static loading test airframe at the CEAT facility at Toulouse.

Analogous considerations and provisions have also been made in the design of the systems, all of which are also being subjected to rigorous full-scale facsimile testing.

The Concorde Formula

In summary, the principal ingredients of a practical and efficient long-range supersonic airliner were found to be a cruising speed of Mach 2.0; a slender ogival delta wing, with controlled separation aerodynamics; a slim 100-140 seat fuselage, with drooping nose section for adequate pilot visibility in low speed flight and on the ground; four moderate pressure ratio Olympus turbojet engines; and a substantially aluminium-alloy structure.





Close-up of a pair of the TRA (Thrust Reverser Aft) variable-area engine exhaust nozzle and thrust reverser/silencer 'clamshell bucket' units.

The Rolls-Royce-SNECMA Olympus 593 axial-flow two-spool turbojet engine of Concorde.

From Concept to Reality

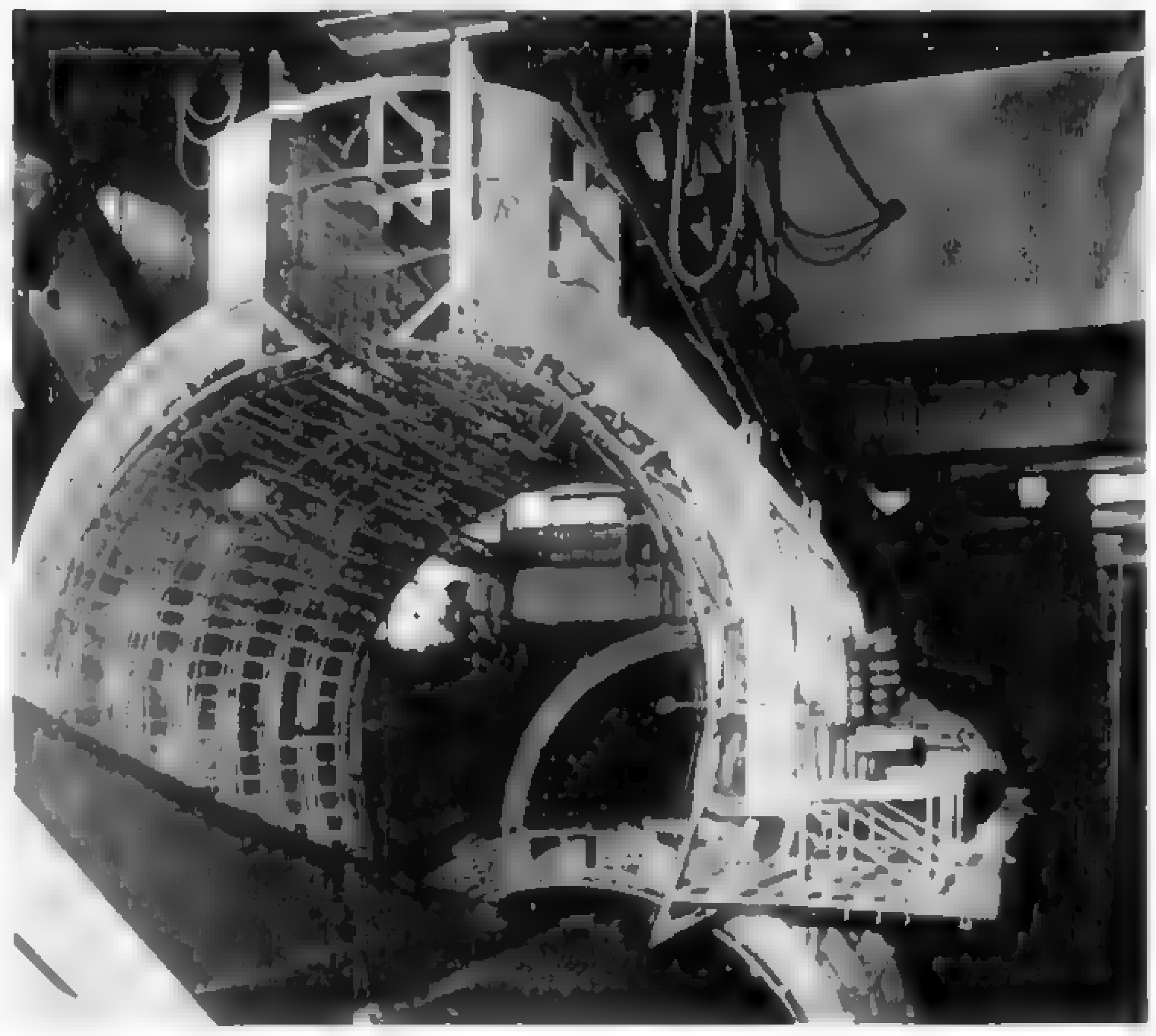
As stated earlier, the independent SST studies in Britain and France during the late-1950s exhibited a remarkable degree of agreement on how to design an SST.

Significantly, both BAC and Sud had decided on the same design cruising speed for the same reasons and both had chosen a low aspect ratio slender delta wing planform, a slim (four-abreast passenger seating) fuselage with a large nose overhang, and a single fin but no tailplane—and hence 'elevons' on the wing trailing edges to combine the lateral and pitching control functions. Another common feature was the location of the underwing nacelles housing pairs of engines fed by rectangular intakes. So too was the side-folding landing gear inboard of these nacelles.

However, Sud believed that a conventional pilots windscreen could be designed with adequate visibility without generating excessive supersonic drag, whereas BAC proposed a more radical downward-hinging nose for this purpose. BAC initially believed that the wing needed to be in the mid-position with the rear spar box passing right across the fuselage—which meant restricting the available passenger space ahead of it—while Sud favoured a low-set wing.

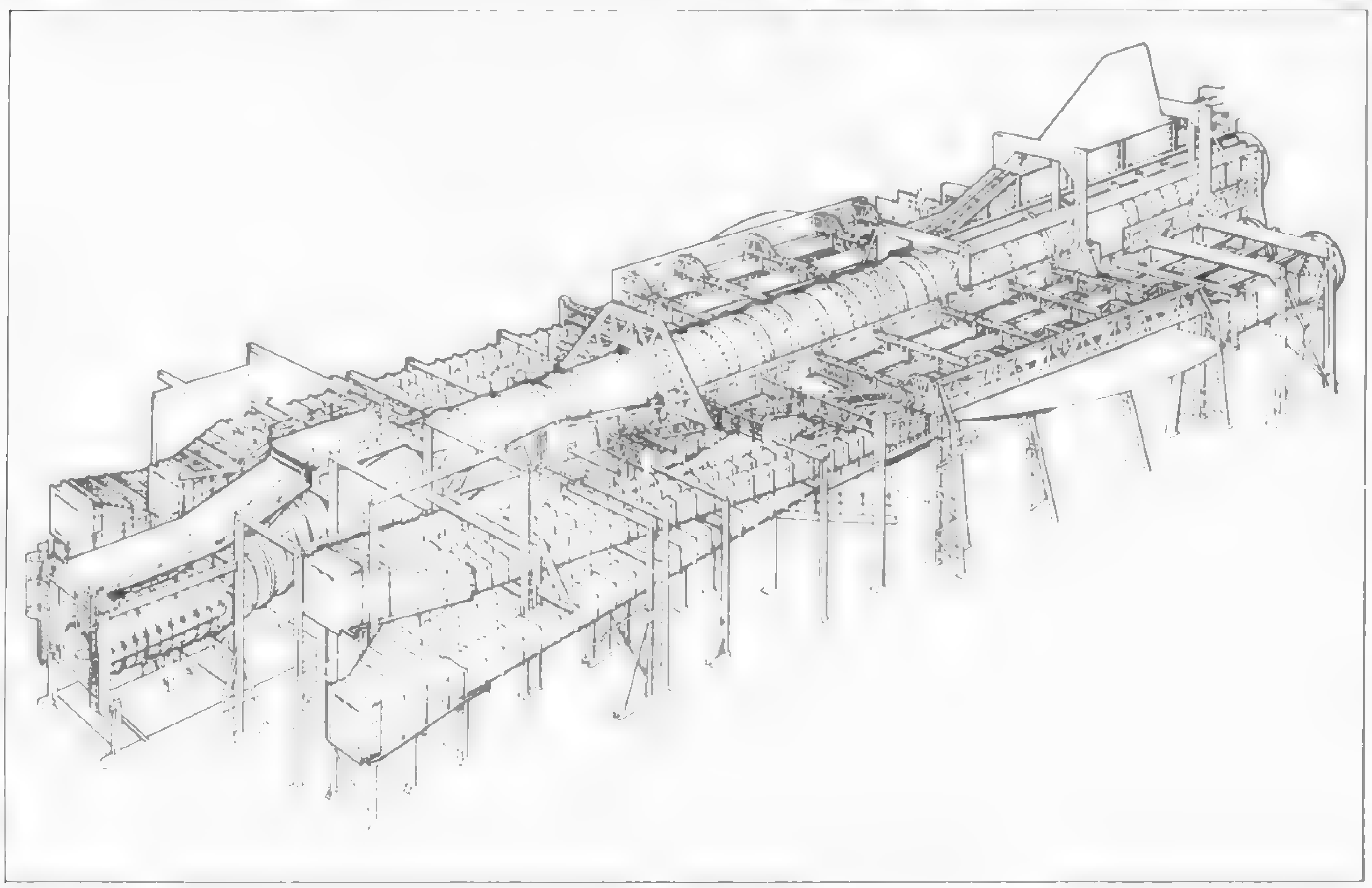
It is perhaps rough justice to say that each company misjudged one major design feature. On the other hand, it is particularly impressive to note just how little the eventual joint design has had to be changed and hence how evidently sound it was.

Nevertheless, a substantial difference did exist in the definition of the operational mission. Based on its most successful experience with the



Part of the Concorde airframe thermal fatigue cycling test facility at the Royal Aircraft Establishment (RAE), Farnborough, England—showing sections of the electrical heat cycling 'glove' being lowered over the rear fuselage.

Underside view of the Olympus-Vulcan flying engine test bed aircraft incorporating a full-scale facsimile of one of Concorde's powerplant units (but with the earlier-type exhaust system)



The complete airframe thermal test rig facility at Farnborough.

Caravelle, Sud proposed a 70-80 seat medium-range 'Super Caravelle', whereas BAC, influenced by its Britannia and VC10 experience, was convinced that a 125-seat aircraft with transatlantic capability was the right course to follow.

The Problems of Compromise

To achieve the joint agreement of 1962 a compromise was made whereby the technical proposals comprised both versions—a medium range one with a ventral entry (à la Caravelle) and a long-range one with the necessary extra fuel in cells in the rear fuselage.

Failure of the two sides to unify their thoughts in a single design at this stage has since proved to be very expensive.

However, working together, the short-haul requirement was slowly eroded away, but a vestige of that early period is to be found in the fact that by the time Concorde enters service three quite distinct versions will have been built—the prototypes (001 and 002), the pre-production aircraft (01 and 02), and the production-standard (201 onwards)—assembled alternately in Britain and France.

From Prototype to Production

When it was ultimately decided to concentrate on the long-range mission, the initial two-version compromise design required considerable revision.

The provision of more fuel disposed around the aircraft centre of gravity demanded more underfloor fuel tanks. In turn, this used up existing baggage space for which an alternative had to be found in the tail cone. This led to the demise of the ventral stairway and hence a second access door was needed on the port side.

Experience gained in the incorporation of these features in the initial prototypes, together with emerging airline influences, led to the need to build two more development vehicles—the so-called 'pre-production' aircraft. Increased passenger capacity was provided by extending the fuselage ahead of the wing and moving the rear bulkhead further back. Four important aerodynamic refinements were also incorporated at this stage: a new fully transparent nose visor to provide greater pilot visibility; new outer wings—to improve airflow by increasing tip chord and revising the camber and twist—thereby reducing the supersonic trim drag; new wing leading edges to improve performance; and improved nacelles to incorporate the higher thrust smoke-free production standard engines and the new TRA thrust reverser/silencer nozzles—providing improved thrust, reduced noise and a substantial weight reduction.

In the second pre-production aircraft (02) a new-design lengthened low-drag rear fuselage shape was also incorporated to reduce supersonic afterbody drag and increase fuel capacity, and further changes were made to the wing leading edge shape to improve low incidence interference with the engine intakes at cruise Mach number.

Construction of the two prototypes began in April 1965. The first of these—Concorde 001 (F-WTSS) assembled by Aérospatiale at Toulouse—was first flown on March 2 1969 by André Turcat, the company's Director of Flight Test. Concorde 002 (G-BSST)—assembled by BAC at Filton—was flown six weeks later on April 9 1969 by Brian Trubshaw, Director of Flight Test of the BAC Commercial Aircraft Division.

The first pre-production Concorde 01 (G-AXDN) was first flown by Trubshaw from BAC Filton on December 17 1971 and the second, Concorde 02 (F-WTSA) which is fully representative of the production aircraft, by Jean Franchi at Toulouse on January 10 1973.

British Government Declares Support

The growing acceptance of Concorde by Government and Airline VIPs from many parts of the world was eventually crowned by the whole-hearted public declaration of support by the British Government which was announced by Mr. John Davies, Secretary of State for Trade and Industry, on December 10 1971. After his Concorde flight he said: 'Concorde is now an aircraft which, having passed through periods of great controversy and debate and argument and discussion, is in a new phase of its life—a new phase because we are now going to see this aircraft become a great commercial proposition, and I think every one of us in the Government feels that there is no effort to be spared to see that the Concorde gets the commercial success that this great project is due.'

This support has since been keenly sustained by Mr. Michael Heseltine, Minister for Aerospace—notably during the big demonstration tour of Concorde 002 in mid-1972 detailed later.

Flight Development

By the time Concorde enters airline service, it will have been more thoroughly researched, tested and proven than any previous commercial aircraft. More than a decade of ground testing and around 3,890 hours of flight testing will ensure safety and reliability.

Seven aircraft are being used in the flight development programme: the two prototypes, 001 and 002, the two pre-production aircraft, 01 and 02, and the first three series production aircraft. The bulk of this flying is being done by the four test aircraft and the three production aircraft will be used mainly for route proving and endurance flying, after which they will be refurbished for airline service.

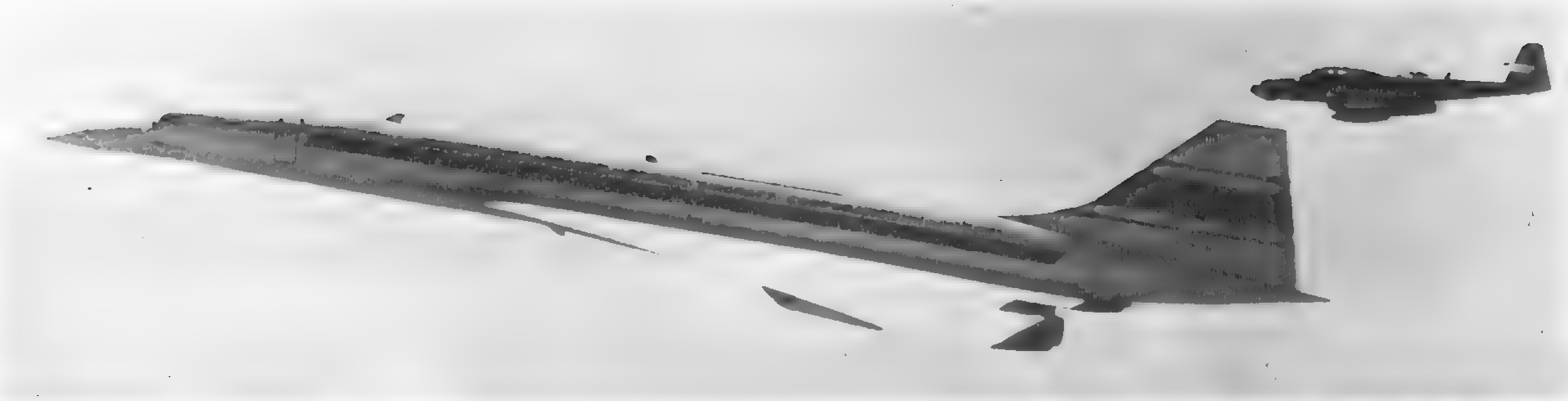
An indication of the scope and thoroughness of prototype testing, 001 and 002 each carry around 12 tons (12.2 tonnes) of specially developed equipment which is capable of

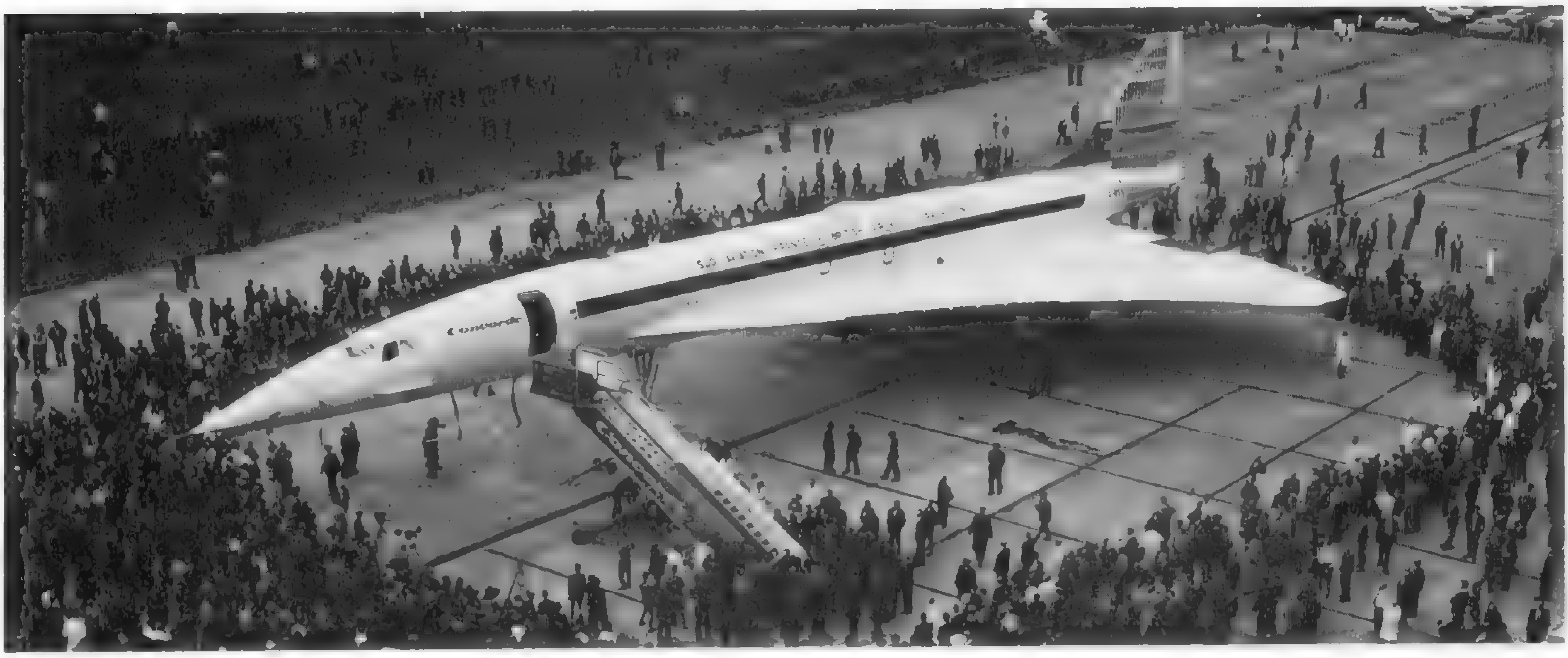
Concorde 001 (F-WTSS) the French-assembled first prototype on its first flight from Aérospatiale's Toulouse factory on March 2 1969. The chase plane is a British-built Meteor NF.11.

Ceremonial roll-out of Concorde 002 (G-BSST) the British-assembled second prototype at the BAC Filton (Bristol) factory on September 12 1968. This aircraft was first flown from Filton on April 9 1969.

Concorde 01 (G-AXDN)—the first pre-production aircraft—seen at Filton outside the famous 'Brabazon' assembly hall shortly before its first flight to Fairford on December 17 1971. Notable new features were the revised flightdeck glazing and visor and longer forward fuselage.

Concorde 02 (F-WTSA)—the second pre-production aircraft—and the first to be representative of the series production standard—seen at Toulouse, France, where it was assembled, and first flown on January 10 1973. The two significant new features seen here are the extended low-drag rear fuselage and the engine thrust reverser/silencer (TRA) units.

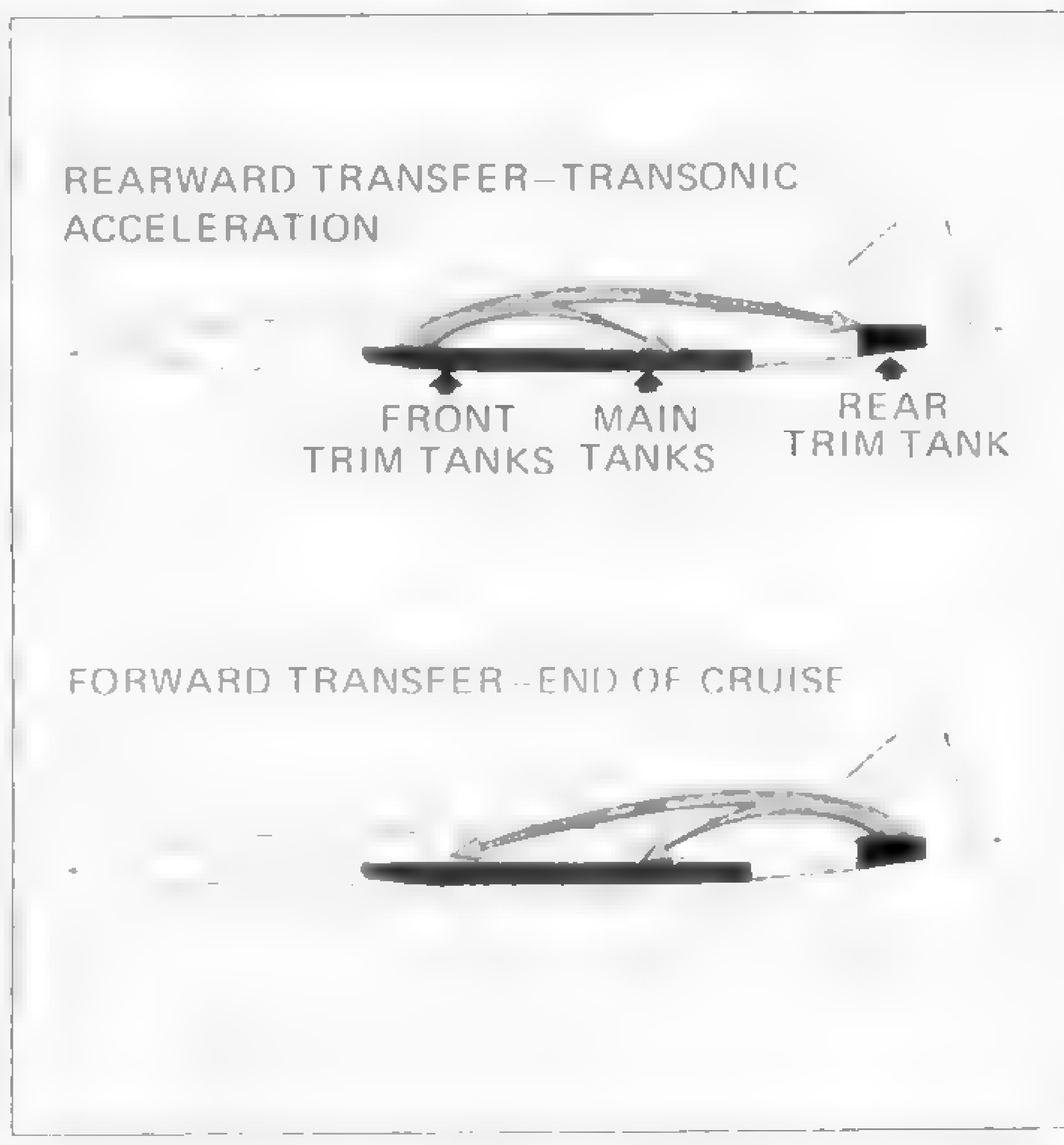





F-WTSA

Concorde's sophisticated wing leading-edge shape—twice revised from the original during flight development.

Main inward-retracting four-wheel bogie landing gear unit.



Concorde's special fuel transfer system used to control the aerodynamic trim change that occurs during transonic acceleration and deceleration.

Main landing gear units being test-retracted on the ground.

The first Concorde to fly incorporating the refinements of the series-production aircraft—low-drag extended rear fuselage, cleaner, quieter Olympus 593 Mk.602s and thrust-reverser/silencer-nozzles—was Number 02, registered F-WTSA, the second production aircraft and fourth Concorde built. F-WTSA was flown from the Aerospatiale factory airfield at Toulouse, France, on January 10, 1973. The pilot was Jean Franchi.

Arthur Sturgess © Profile Publications Limited/British Aircraft Corporation 1973

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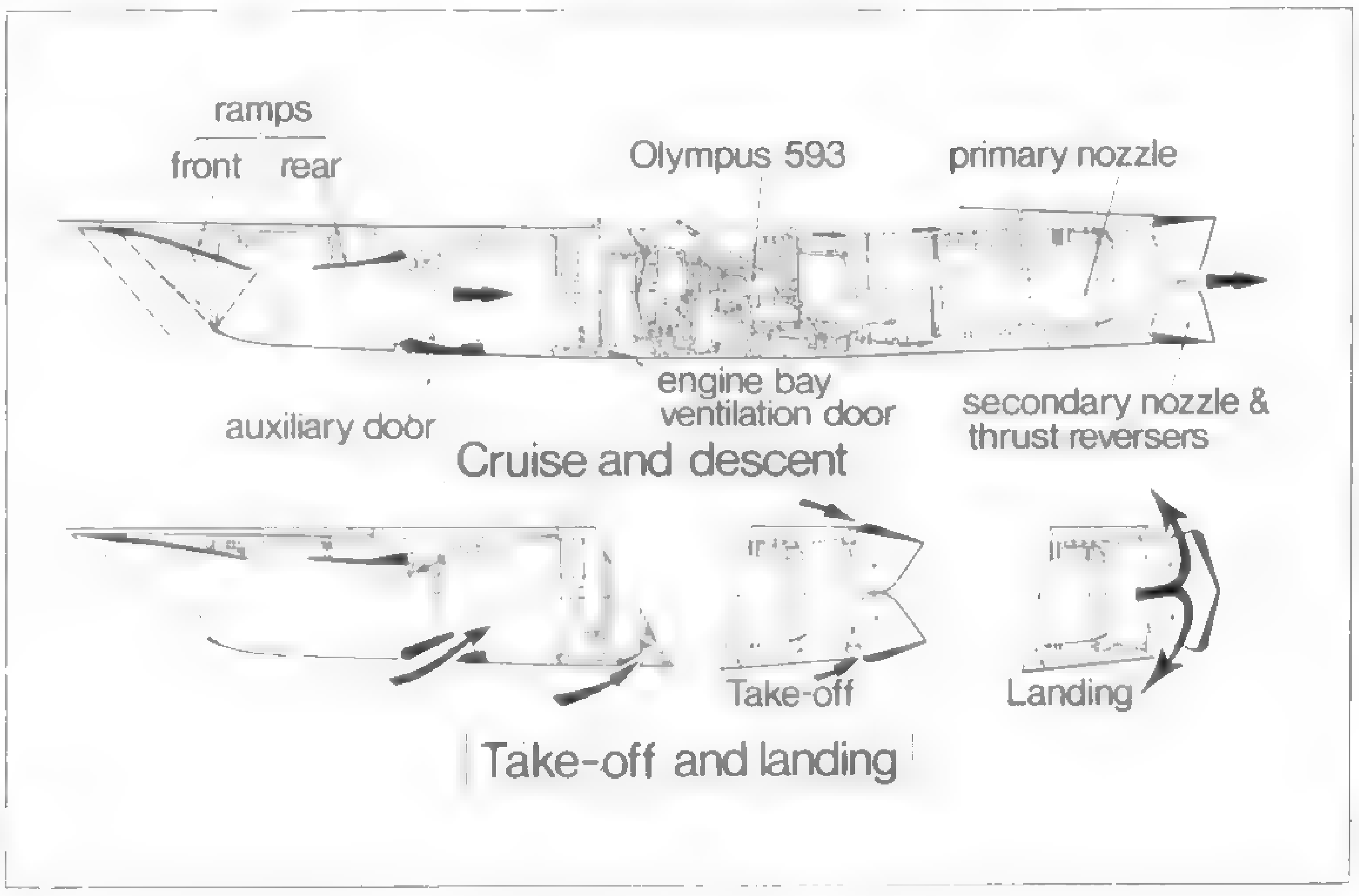
The ogival curve of the delta wing leading edge of Concorde.

Sequence of operation of variable geometry powerplant air intake and exhaust systems.



The long forward-retracting twin-wheel nose landing gear required to accommodate the characteristic high incidence approach and landing attitude of delta-winged Concorde.

Close-up of the extended low-drag rear fuselage of Concorde 02.

simultaneously measuring and recording 3,000 separate data points.

Progress to date has been highly satisfactory with both the British and French flight test teams, with remarkably few problems encountered, and performance and handling have been progressively ratified by many airline pilots throughout the operational speed range.

Production Standard Concorde

The series production standard Concorde will be 203 ft. 9 in. long (61.66 m.); 37 ft. 1 in. high (11.32 m.); and 83 ft. 10 in. (25.56 m.) wingspan; carry 108-144 passengers; be powered by four Rolls-Royce Olympus 593 Mk602 turbojets of 38,050 lb. (17,260 kg.) static thrust each; cruise at a speed of Mach 2.0 (about 1,300 m.p.h. or 2,092 k.p.h.) at altitudes of 50,000 to 60,000 ft. (15,240 to 18,290 m.); have a range capability of 3,853 miles (6,196 km.); and a maximum take-off weight of 389,000 lb. (176,450 kg.).

The design payload of 20,000 lb. (9,072 kg.) on entry into service is equivalent to 100 passengers and baggage matched to the Paris-New York sector. This payload capability is to be increased to 24,000 lb. (10,886 kg.) two years after entry into service. The volumetric capacity is 28,000 lb. (12,701 kg.).

Series Production

From the prototypes onwards, Concorde manufacture has been progressively organised on a series production basis with fully developed tooling.

The British share of Concorde manufacture is the responsibility of the BAC Commercial Aircraft Division, the Filton (Bristol) factory of which is the 'control' and final assembly centre. The Weybridge (Surrey) factory is the largest single contributor to the entire Concorde programme and builds and equips virtually all British-made components—the nose and forward fuselage, the rear and tail fuselage, and the fin and rudders. The droop-nose is built at the BAC Hurn (Bournemouth) factory and the engine nacelles at Filton and BAC Preston. Flight testing of British-assembled Concordes is at Fairford (Gloucestershire).

The French share—which comprises the wing and centre fuselage is handled by the Aérospatiale factories at Toulouse, Marignane, St. Nazaire, Bourges and Bouguenais. Flight development is conducted at Toulouse.

The Olympus engine is made at the Rolls-Royce factory at Patchway (Bristol) and the thrust reverser/silencer unit by SNECMA at Melun-Villaroche, near Paris.

Because there are two final assembly centres in the overall Concorde production programme —at Filton and Toulouse—it became essential to organise the dispersed component manufacturing programme in Britain and France in such a way that as much equipment as possible be installed at each component manufacturing centre in order to eliminate the 'double learning factor' that would be entailed if all the equipment was installed at the final assembly stage. Additionally, this enabled considerable benefit to be derived from the greater working access available at the component build stage.

Typifying this process is the nose and forward fuselage built and equipped at BAC Weybridge. This 50 ft. long component comprises the flight deck and engineer's station, the forward part of the passenger cabin and the nose landing gear bay. It is equipped to a very high standard with electrical, hydraulic, flying control and air-conditioning systems and cabin insulation and incorporates 25,000 parts and 90 miles of wiring.

The completion of these major airframe components to such a high standard away from the final assembly centres, is unique. It is the first programme in which major components for such a sophisticated aircraft have been pre-equipped to such an advanced standard and high quality of completion prior to final assembly of the complete aircraft.

The complexity and compact nature of Concorde engineering has demanded a high level of co-ordination within the many BAC and Aérospatiale factories and subcontractors and suppliers involved in Britain and France.

Quality control has also had to be of a high order, especially in respect of the complex interfaces between components which clearly must mate precisely in final assembly.

Odd-numbered aircraft (201, 203, 205 etc.) are being assembled in France and the even-numbered ones (202, 204, 206 etc.) in Britain and capacity has already been established for a combined output of three aircraft per month.

Full authorisation for the first 16 series production Concordes has already been given by the two Governments, plus the procurement of long-dated parts and materials for a further six aircraft. This means that the total programme—including prototype, pre-production and test aircraft—now embraces 28 Concorde airframes.

Concorde—The Great Collaboration

The task of organisation and management that stemmed from the Anglo-French agreement of 1962 was unprecedented in the aerospace business, not only because the aircraft was to be developed on a collaborative basis but also because of its sheer size and complexity.

Grappling with the problems of working with two frequently changing national governments and policies, two languages, monetary and measurement systems; two design, assembly and flight test centres separated by physical and national barriers 600 miles apart; and the co-ordination of around 800 subcontractors and suppliers—have been the principal challenges of collaboration and programme management.

Component manufacturing breakdown and responsibilities.

Nose and forward fuselage (Component 30) assembly line at BAC Weybridge. These (and all other major airframe components) are equipped to a high standard at this stage prior to transfer to the Filton and Toulouse final assembly centres.

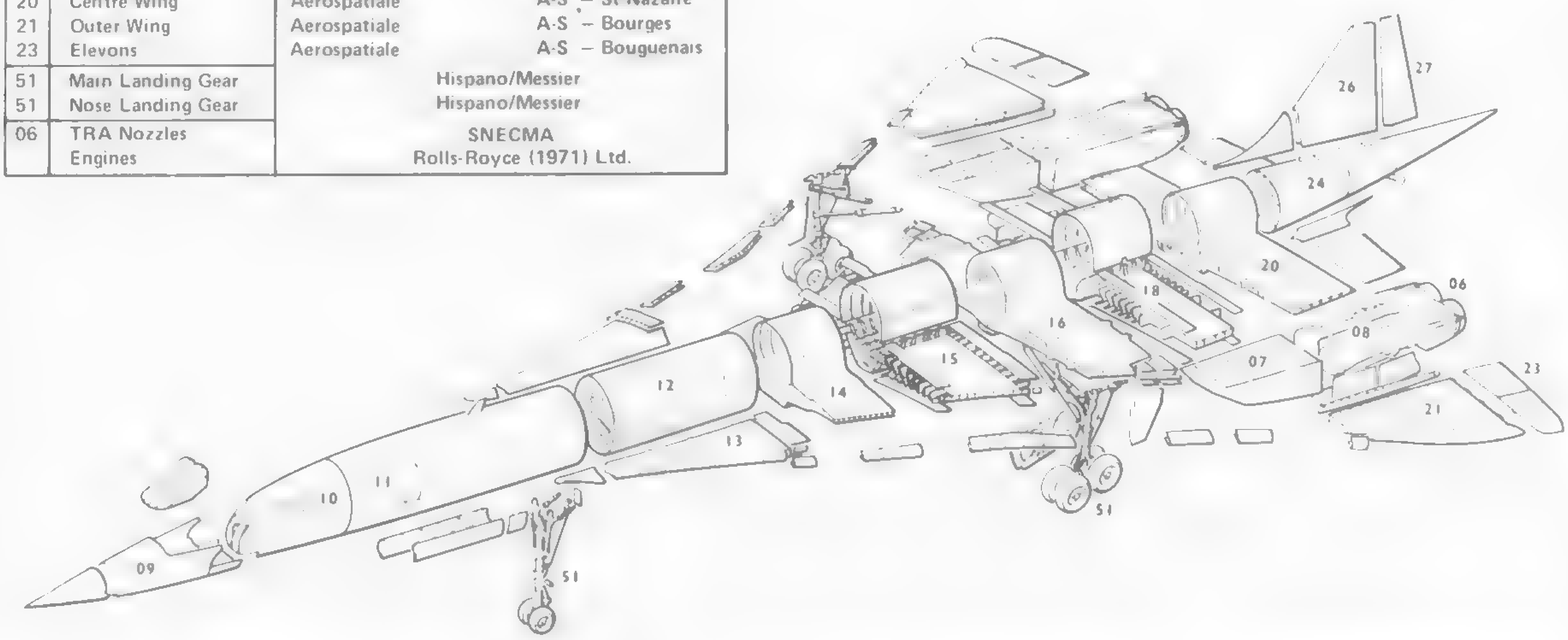
Part of the 12 tons (12.2 tonnes) of flight test measuring and recording equipment carried by the Concorde prototypes 001 and 002.

PRODUCTION MANUFACTURE BREAKDOWN – MAJOR ITEMS

COMPONENT		DESIGN	MANUFACTURE
07	Air Intakes	BAC	BAC – Preston
08	Engine Bay	BAC	BAC – Filton
09	Droop Nose	BAC	BAC – Hurn
10	Nose Fuselage	BAC	BAC – Weybridge
11	Forward Fuselage	BAC	BAC – Weybridge
12	Intermediate Fuselage	BAC	A-S – Marignane
24	Rear Fuselage	BAC	BAC – Weybridge
26	Fin	BAC	BAC – Weybridge
27	Rudder	BAC	BAC – Weybridge
13	Forward Wing	Aerospatiale	A-S – Bouguenais
14	Centre Wing	Aerospatiale	A-S – Marignane
15	Centre Wing	Aerospatiale	A-S – Bouguenais
16	Centre Wing	Aerospatiale	A-S – Toulouse
18	Centre Wing	Aerospatiale	A-S – Toulouse
20	Centre Wing	Aerospatiale	A-S – St Nazaire
21	Outer Wing	Aerospatiale	A-S – Bourges
23	Elevons	Aerospatiale	A-S – Bouguenais
51	Main Landing Gear	Hispano/Messier	
51	Nose Landing Gear	Hispano/Messier	
06	TRA Nozzles	SNECMA	
	Engines	Rolls-Royce (1971) Ltd.	

SYSTEMS RESPONSIBILITIES

BRITISH AIRCRAFT CORPORATION	AEROSPATIALE
Electrics	Hydraulics
Oxygen	Flying Controls
Fuel	Navigation
Engine instrumentation	Radio
Engine controls	Air conditioning supply
Fire	
Air conditioning distribution	
De-icing	



A few basic statistics give dimension to the current scope and magnitude of the Concorde task.

Around 24 thousand people are now engaged directly on the programme in Britain and a similar number in France. Several times that number are involved indirectly. Expenditure is currently running at a level equivalent to £1½ million a week in each country. These numbers will increase substantially when full series production is established. The co-ordination of activity on this scale is clearly a very formidable management task.

Task Distribution

The industrial task distribution was based on the principle of an equal sharing of work, expenses and the proceeds of sales.

Because the Olympus 593 engine constituted 60 per cent of the powerplant package the overall 50/50 split between the two countries was maintained by BAC being given approximately 40 per cent of the airframe and systems i.e. the forward and aft sections of the fuselage, the fin and rudder, engine nacelles, and the electrical, oxygen, fuel supply, engine controls and instrumentation, fire warning and extinguishing systems, air-conditioning distribution and de-icing systems. On the French side, Sud was thus given the other 60 per cent of the airframe i.e. the wings and the centre fuselage plus the hydraulic, air conditioning supply, flying controls, and radio and navigation systems —and SNECMA became responsible for the remaining 40 per cent of the powerplant i.e. the re-heat, exhaust and thrust reverser/silencer nozzle assembly.

In practice, work contracts on BAC and Rolls-Royce are placed by the British Government and those with Aérospatiale and SNECMA by the French Government. Each Government and company is then responsible for the control of expenditure within its own area.

Financing the Concorde development and production programmes is being wholly undertaken by the two Governments. This means that they are intimately involved in all aspects of the programme, including its commercial exploitation, with a mandate to scrutinise and control the deployment of funds provided by their taxpayers.

Programme Management Directorate

In addition to specifying the allocation of development and manufacture, the 1962 Treaty also laid down the principles of the basic organisational structure for the programme. While there have been changes in the meantime to reflect the evolving maturity of the programme, these fundamental principles have stood the test of time extremely well and continue to be the basis of the programme supervision and administration.

Whereas the day-to-day management is necessarily the responsibility of the manufacturers, officials of the two Governments play a fully complementary supervisory role. Hence Boards of management were established at both Government and industrial levels.

The overall management policy instrument at Government level is the Concorde Directing Committee (CDC) with members drawn from the two countries 'to supervise the progress of the work, report to the Governments and propose the necessary measures to ensure the carrying out of the programme.'

The Chairmanship of the CDC rotates periodically between Britain and France. Representation on the British side is drawn from the Department of Trade and Industry (which is currently responsible for the overall policy of the Concorde programme in UK), the Procurement Executive of the Ministry of Defence (whose headquarters, branches and R. & D. establishments—in particular the RAE and the NGTE—provide considerable assistance to the Concorde programme), and the Treasury. The French members of the CDC cover a similar span of responsibilities.

The CDC is supported by the Concorde Management Board (CMB) which is composed of senior civil servants. Under the general direction of the CDC, this Board is responsible for the day-to-day oversight and co-ordination of the programme. Chairmanship of the CMB rotates annually between the British and French, alternating between the Director-General, Concorde—DoTI and the Directeur General Projects de le Secretariat Général a l'Aviation Civile respectively.

Reporting to the CMB are the 'Aircraft Committee of Directors' and the 'Engine Committee of Directors' which together comprise the senior industrial executives.

Two governments and four major industrial companies are thus inter-linked in the Concorde programme by means of four committees of management, each of which consists of officials from each nation, duplicating responsibility, chairman and deputy, functional directors and deputy, with seniorities alternating but always with equal representation.

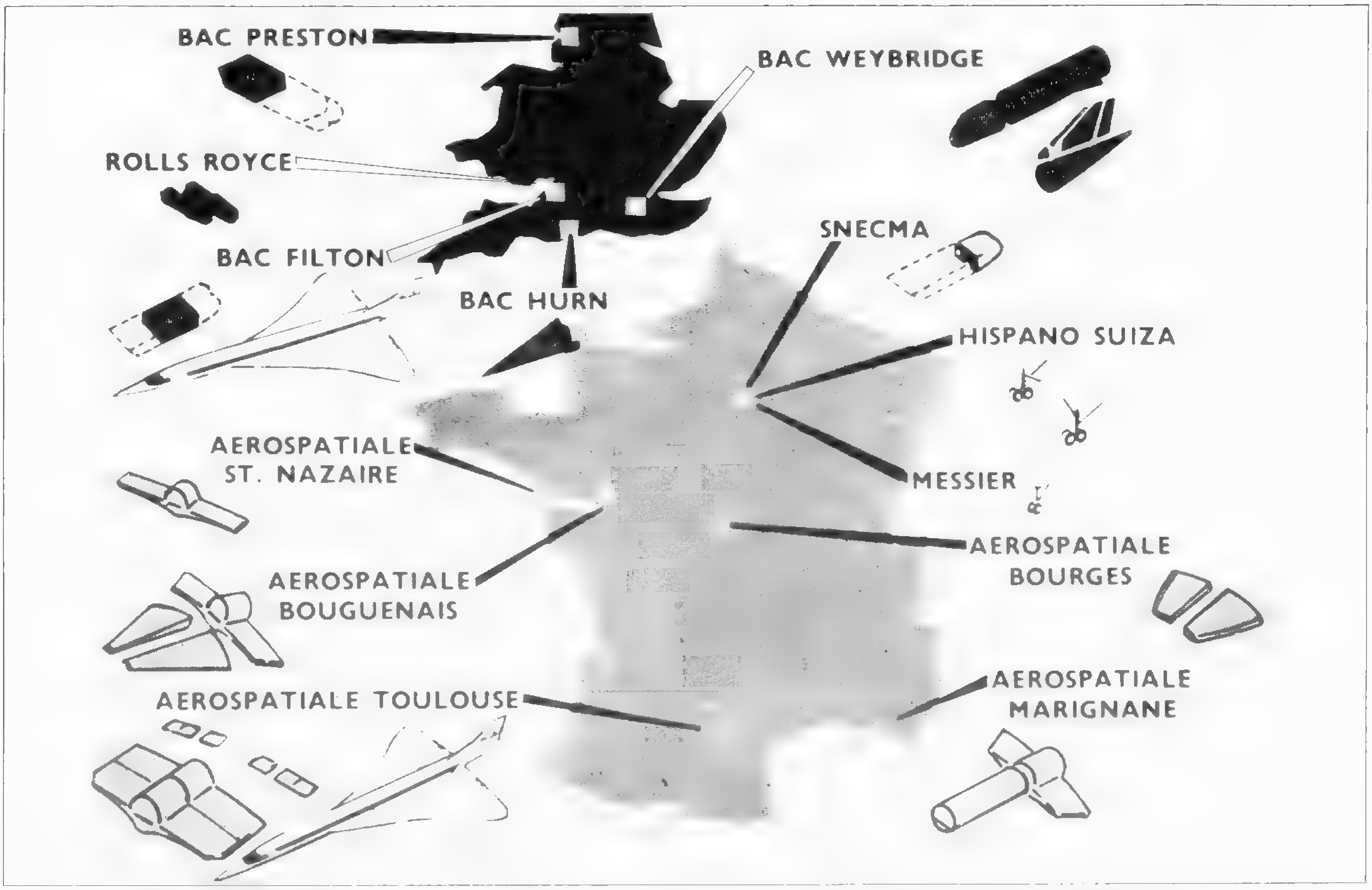
This arrangement has now worked for more than a decade because, as Sir George Edwards puts it: 'Success has revolved around personalities, the great desire for each to understand the other, to respect his point of view, and to get on with him as a man.'

While the two Governments and their Ministers have undergone frequent and fundamental changes, and there has been a succession of leaders on this side of the Concorde team, industrial chiefs have been subject to very few changes.

The progress of Concorde from conception to hardware has been strongly characterised by the interplay of personal characteristics of its industrial leaders.

Geographical location of Concorde manufacturing centres.

Concorde Governmental and Industrial Programme Management Directorate.

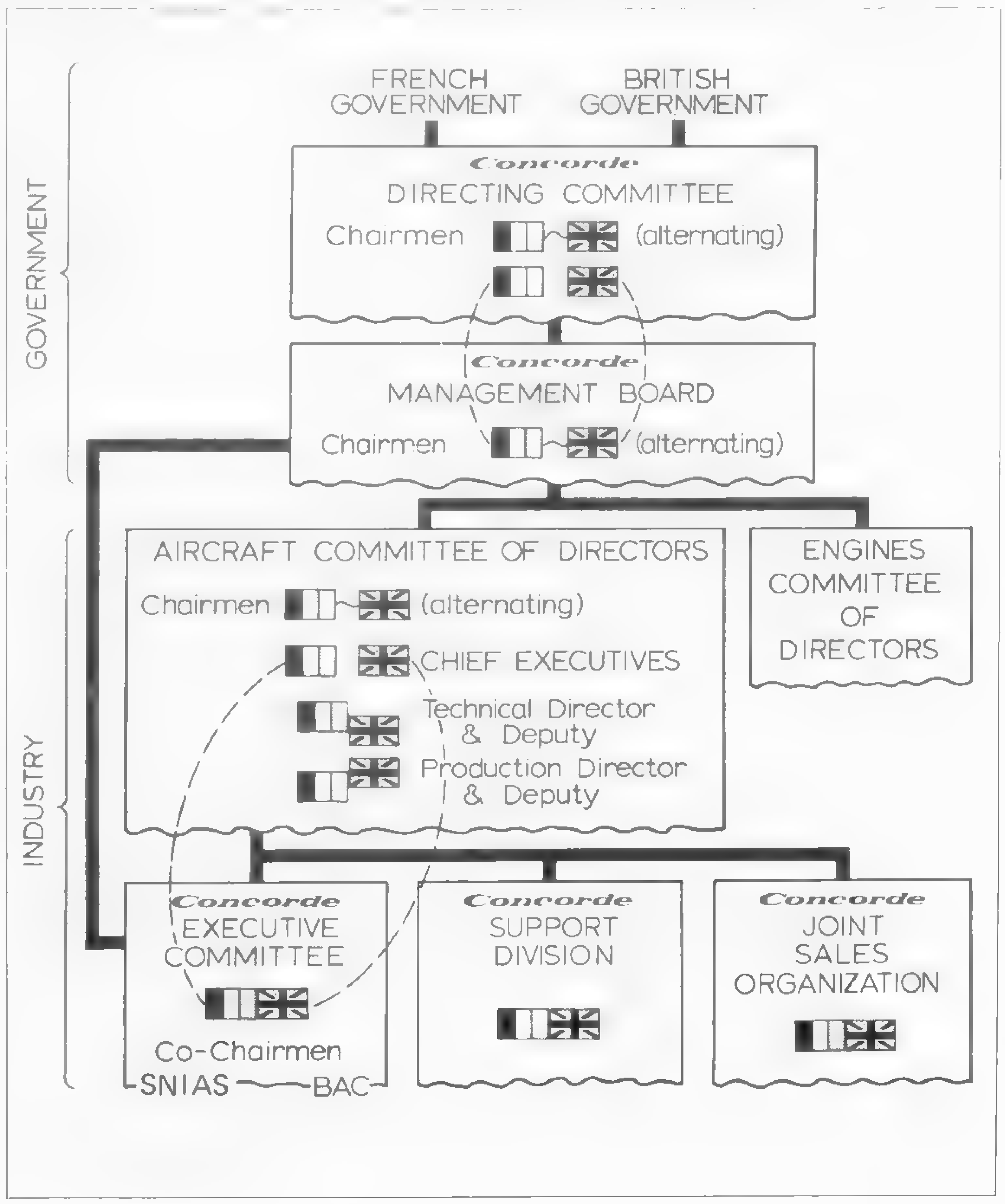


Sir George Edwards, who has lead the British Concorde team with outstanding acumen since its inception, accredits 'the great breakthrough' to the late General André Puget—President of Sud Aviation 1962–66—who was first given the job of managing the Concorde programme in France. 'These were critical times, when the Concorde project was going to be made or broken', says Sir George. 'It was Puget, more than anyone else, who saw to it that Concorde would be made.'

Significantly the two current industrial leaders —Sir George Edwards of BAC and General Henri Ziegler of Aérospatiale—have a long working relationship. They first worked together in 1952 when Sir George was head of Vickers-Armstrongs (Aircraft) and selling Viscount prop-jets to Air France which General Ziegler headed at that time. Later they worked closely together again on the BAC-Breguet Jaguar military strike/trainer aircraft programme when General Ziegler was in charge of Breguet Aviation. General Ziegler has been President of Aérospatiale since 1968 and has made a major impact during the critical period from prototype first flight to the initiation of first customer contracts.

Collaboration in Practice

The first practical link in Anglo-French collaboration was forged by Sir George in 1958 when he arranged for the fin and tailplane components of the Super VC10, then in production by Vickers-Armstrongs at Weybridge, to be built by Sud-Aviation at its St. Nazaire factory—



fundamentally to establish the plain human job of working together. This initiated the essential experience of interchange of personnel, working drawings and manufacturing techniques, and, of course, of language and measurement conversions. The result was a complete success and a vital preface to the large scale production dispersal on Concorde that has since been organised in Britain and France.

Language and measurement have not, in fact, resulted in any insurmountable problems. Manufacturing drawings carry both English and Metric units. Each side designs in its own units and then the corresponding equivalent is added as a routine. Thus it is fair to say that, despite the current topicality of 'Metrication', Concordes designers overcame this problem long ago.

A much more formidable task has been the mutual agreement of standards for materials—normally a routine. A special organisation was set up for this purpose and to date more than 2,500 joint standards have been established.

The inevitability of different approaches to the solution of technical problems has at times proved to be most arduous and frustrating. However, the value of the ensuing cross-fertilisation of ideas and practices has been amply vindicated by the substantially trouble-free flight development of Concorde so far, especially in view of the radical advances in so many areas compared with the previous levels of technology of which the partners had experience.

Communications

As in all successful businesses, good communications have been essential. This has been especially evident in the complexities of the joint design engineering organisation which totals over 2,000 people.

There are teams of each nationality resident in each other's camps to hammer out the day-to-day problems associated with their particular responsibility because each aeroplane, whether it be assembled in Filton or in Toulouse, is assembled from components and equipments produced from many sources in both countries.

International communications consist of tie-line telephone and telex links and land-line facsimile reproducing facilities, while for physical transportation there is a fleet of communications aircraft.

BAC currently uses an eight-seat Hawker-Siddeley H.S.125 jet (G-AVPE) which operates a thrice weekly schedule between Filton and Toulouse and numerous VIP flights as required. Rolls-Royce also uses an eight-seat H.S.125 (G-ATPB) for personnel and an H.S. Argosy (G-APRM) freighter for engines and parts transport between the UK and France.

Aérospatiale uses a 12-seat Nord 262 propjet (F-BLKE) for personnel transport. The Aero-Spacelines G-201 'Guppy' freighter (F-BTGV), operated by Aéromaritime of France, is now used for the international transport of the majority of large Concorde airframe components.

Marketing the Twelve-hour World

Concorde's ability to halve journey times and to enable the longest journey on earth to be completed in a single day will open up an entirely new vista in international air transport marketing.

First practical evidence of this came in September 1971 when Concorde 001 made an exacting and impressive demonstration tour to South America.

This was confirmed on a wide-ranging geographical basis by the 45,000 mile sales demonstration tour of the Middle and Far East, and Australia by Concorde 002 between June 2 and July 1 1972. Flying substantially faster and higher (Mach 2.05 at 57,000 ft., 17,373 m.) than any previous commercial aircraft, Concorde established its huge speed advantage while fitting effortlessly into the traffic patterns of thirteen international airports.

The most arduous and ambitious sales demonstration mission ever undertaken by a prototype aircraft, this tour was successfully completed exactly on time with only minor and insignificant faults and delays—of the kind that a fully-established current jetliner experiences in service—and with a significant improvement in predicted fuel consumption.

Concorde flew in 62 hours what scheduled subsonic airliner flights would have taken a total of 24½ hours longer.

On the ground, Concorde's serviceability was quite outstanding and in four weeks of almost constant flying only six hours were lost through purely technical reasons. This was achieved by a small support team travelling in RAF VC10 and Belfast aircraft and without the normal in-service benefits of service support and spare part supplies at most major international airports.

Contributing to Concorde technology (see also page 12)

7 Dassault Mirage IV-01; *June 1959.*

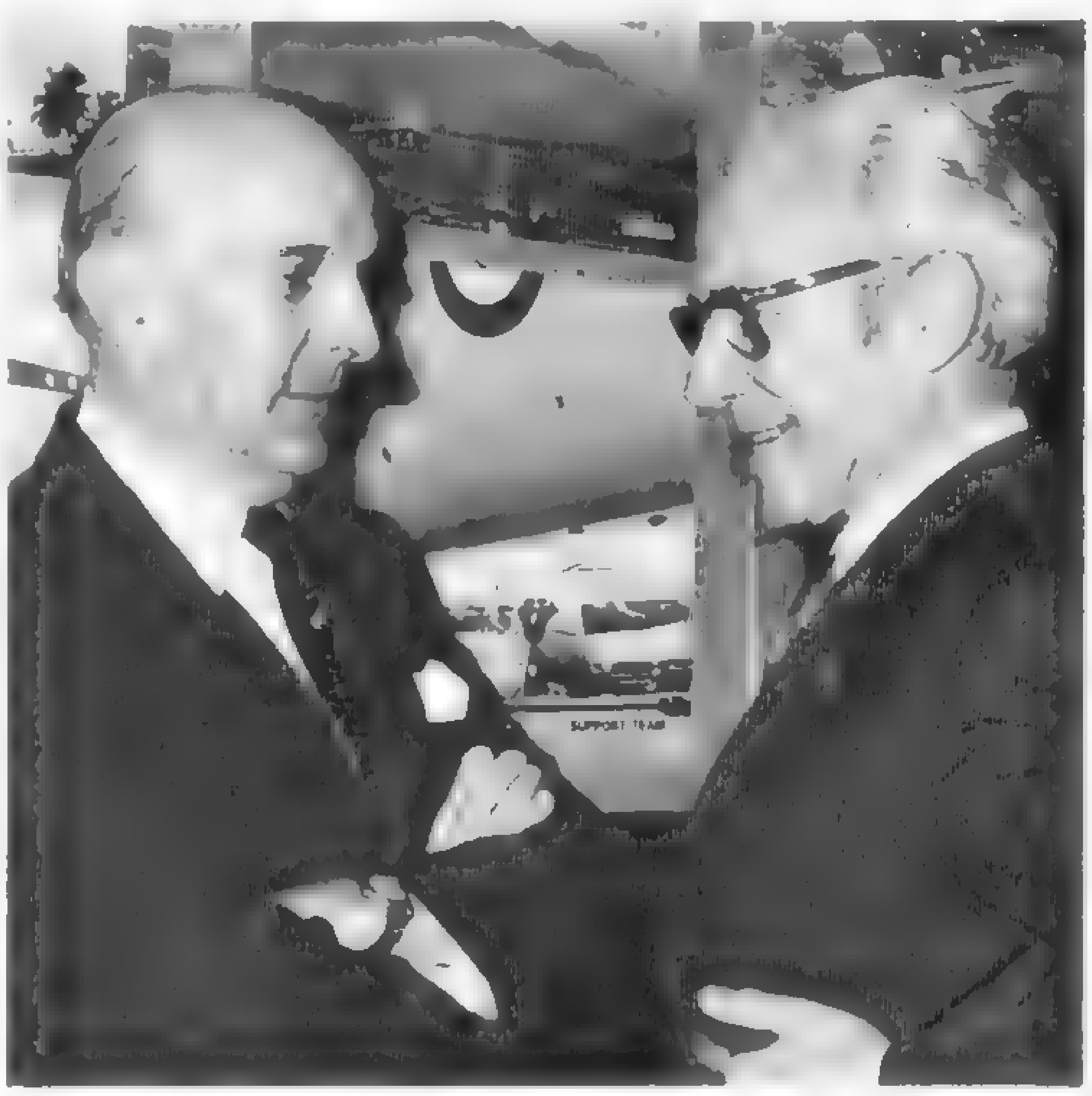
8 Handley Page H.P.115 *(XP841); August 1961.*

9 BAC (Bristol) Type 188 *(XF926, 2nd. prototype, c/n. 13519); April 1963.*

10 BAC Type 221 *(WG774, ex-F.D.2); May 1964.*

11 BAC TSR.2 *(XR219); September 1964.*

12 Hawker Siddeley (Avro) Vulcan *(XA903, Olympus engine test bed); September 1966.*



Concorde's industrial programme leaders: (left) Sir George Edwards, Chairman of British Aircraft Corporation and (right) General Henri Ziegler, President of Aérospatiale of France.

The late General André Puget—first French industrial leader of the Concorde programme.

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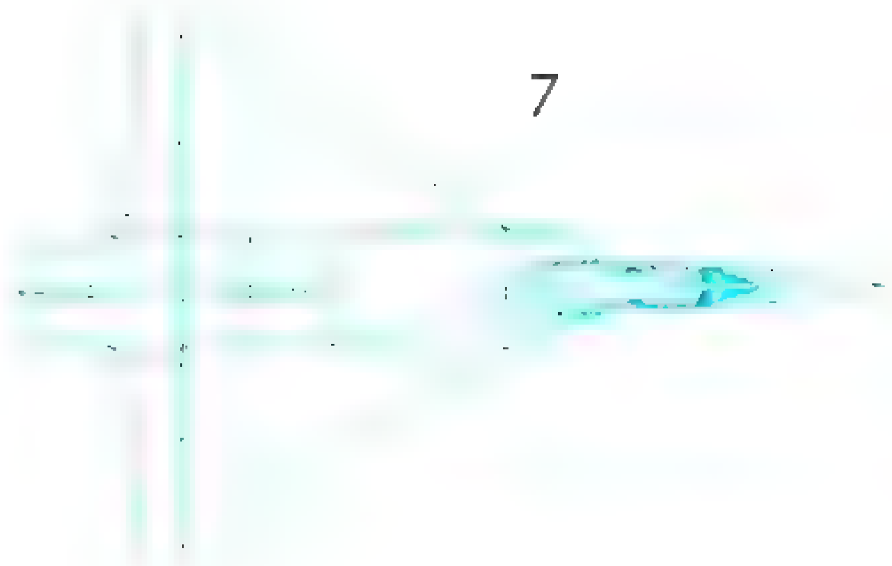

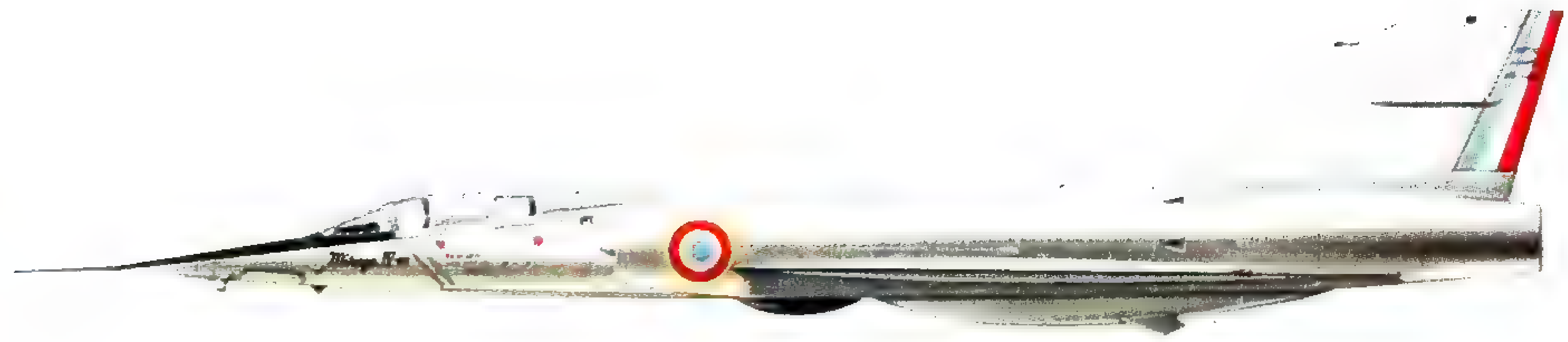

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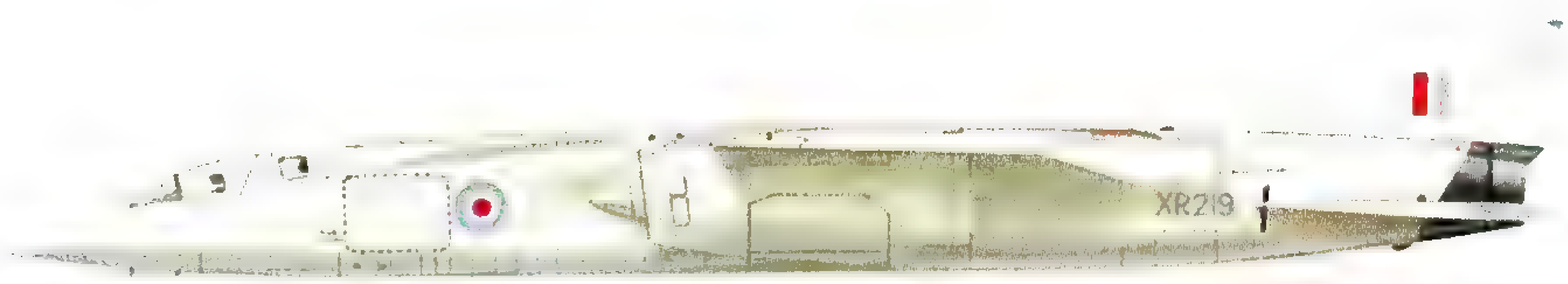

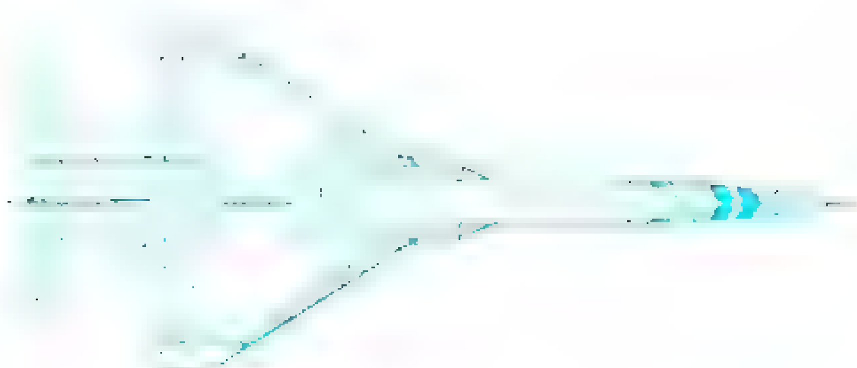

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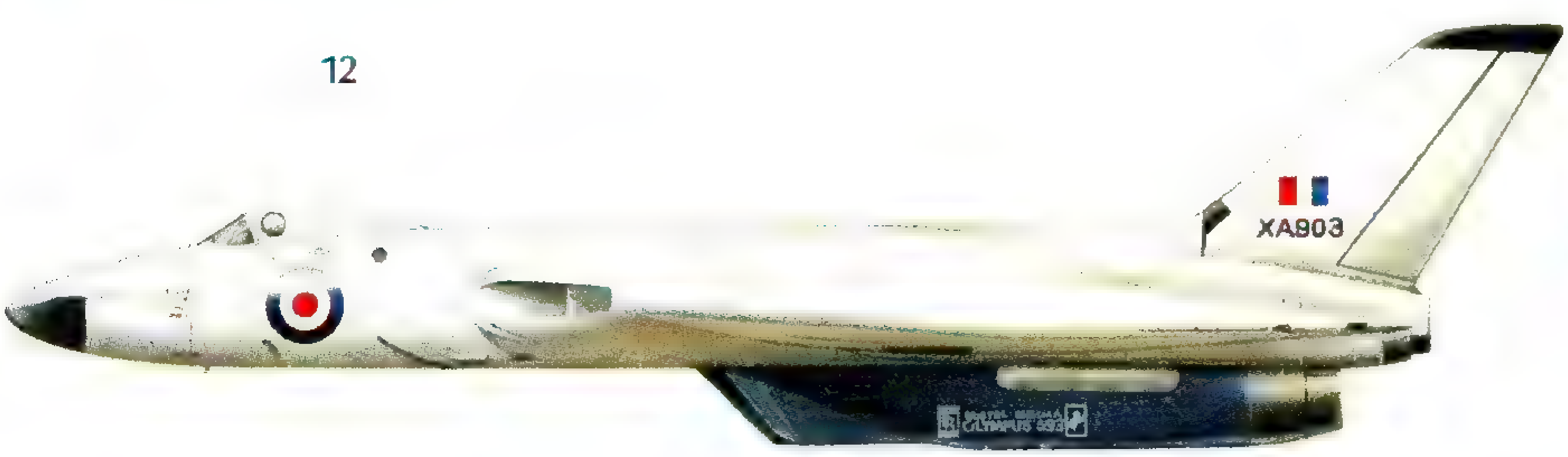
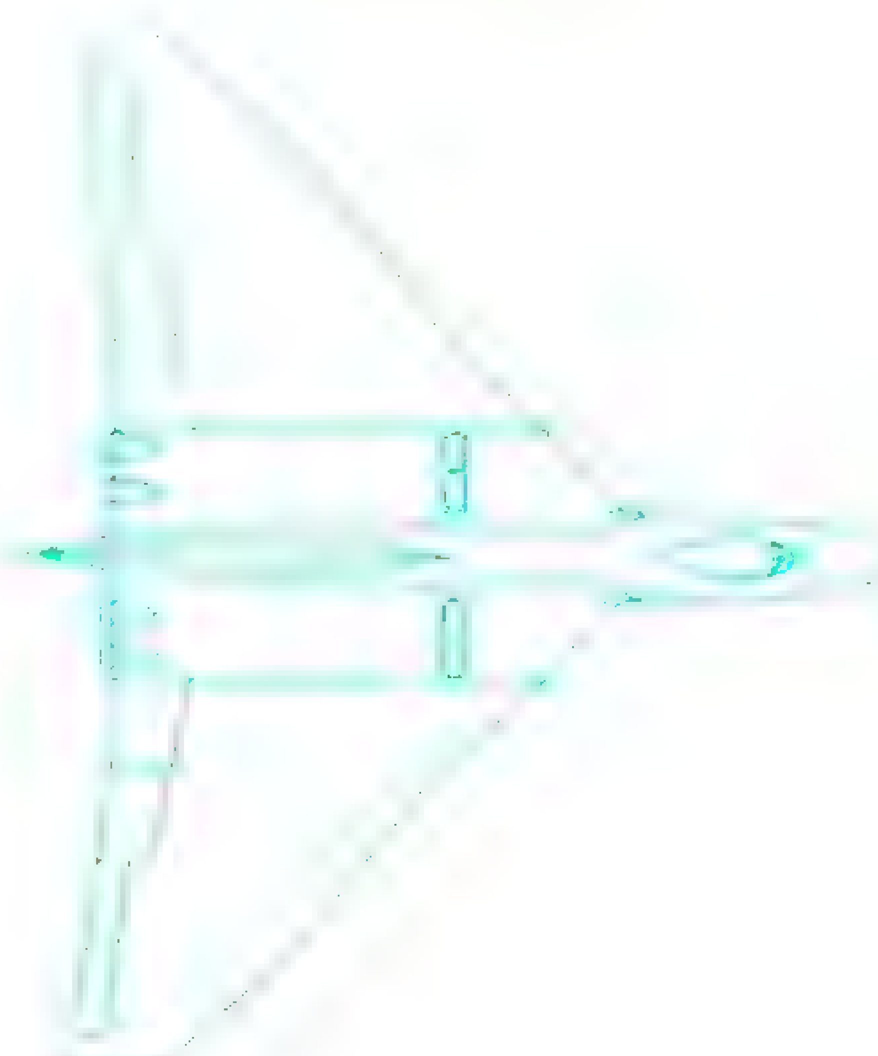




Airline chiefs, VIPs and over 300,000 people in 12 countries saw Concorde for the first time during this tour.

Commenting on this exceptional performance Sir George Edwards pointed out: 'We satisfied ourselves that we could meet the original design objective of operating in and out of existing airports and using existing traffic control procedures. When one remembers that the advent of the big American subsonic jets had to be almost universally accompanied by major extensions to airport runways and facilities, this is quite an achievement.'

New Marketing Concept—The Mixed Fleet Philosophy

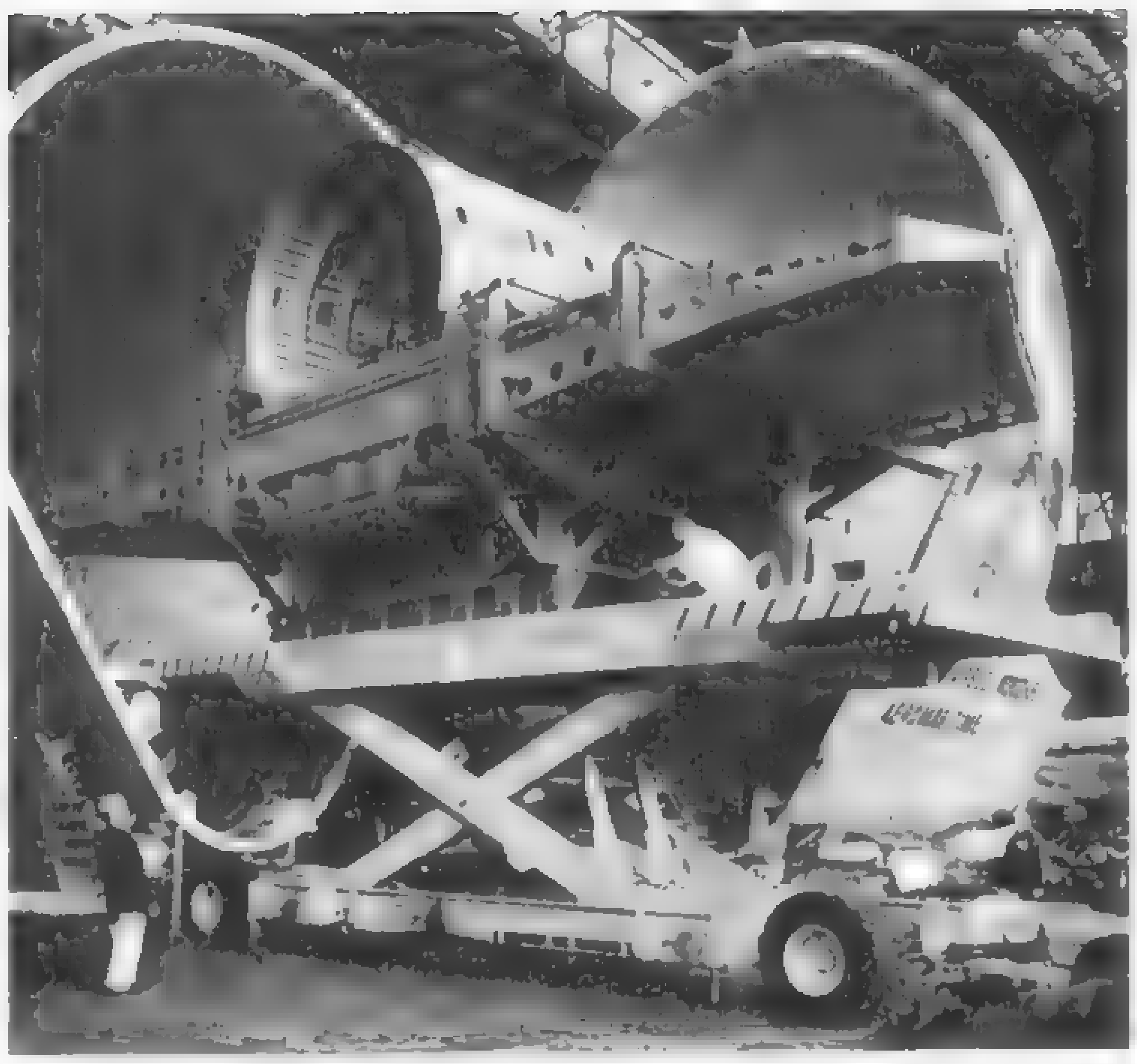
The situation that will arise when Concorde and the wide-bodied subsonic jets are in service together has no precedent in aviation history. There will for the first time be two new, entirely different but complementary, types of air transport available, one offering advantages of high speed and the other offering advantages of high capacity.

To explore the economic potential of both types to full advantage, the manufacturers have evolved an imaginative new marketing concept for Concorde customers. The core of this is the advocation of a 'mixed fleet philosophy' of both supersonic and subsonic services. Both types of aircraft could be operated as single-class units and there are cogent economic and operational arguments to support this.

Supersonic services would cater at peak times for the businessman, and others to whom time means money, and subsonic services would be operated at fares and frequencies calculated to preserve a profitably high payload factor.

Although the business clientele represents a minority of the total traffic, it is an important and stable element which by its very nature is normally not eligible for promotional fares; one major intercontinental airline has recently established that its business traffic, amounting to about 25 per cent of the total, produces more than 40 per cent of its total revenue. Business travel is, therefore, subsidising the much less remunerative leisure traffic.

A great deal of interest has thus been generated in what has come to be known as the 'single class' philosophy as the most expeditious means of integrating Concorde into their fleet operations. This visualises the use of Concorde as a single class premium-fare vehicle catering for the business traffic, leaving the high capacity subsonic jets to be used as single-class vehicles catering for the mass travel market. In this way both types of airliner would be used in a role for which they are specifically suited, and it can be demonstrated that a correct mix of Concordes and subsonic airliners produces a higher level of profitability than an all-subsonic fleet of similar capacity.



Concorde centre fuselage and wing section (Component 15) being unloaded from the Aéromaritime 'Super Guppy' freighter at Filton.

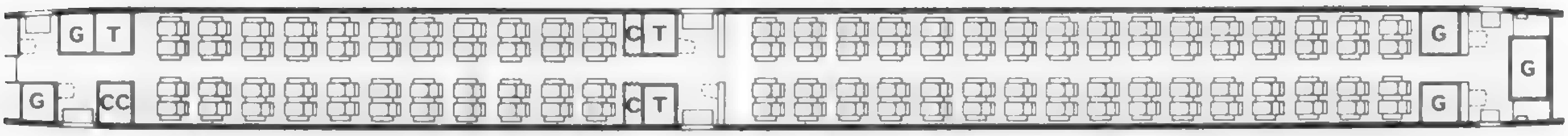
Because Concorde will be offering a clearly superior product—halved journey times—it is argued that it is only reasonable that this should command a higher fare and it has therefore been proposed that the interior should be configured to a 'Superior Class' offering superior standards of comfort and cabin service, but at a fare level of around 15 per cent below the current first class fare.

At present, for a surcharge of about 50 per cent over the standard economy fare level the first class passenger enjoys a somewhat higher standard of cabin amenity than the economy class passenger, but does not receive the advantage of speed.

Using the full-scale mock-up at Filton, the standard of cabin comfort and service facilities for this new concept, comparable with those of present-day first class cabins, has been demonstrated to Concorde customer airlines. The overall result is that these standards can be offered, in conjunction with enormous passenger-appeal of halved journey times, at a fare level of 15 per cent below first class (or at a premium of about 35 per cent above the economy fare level) and a healthy economic return on investment is predicted.

In this way, Concorde is confidently expected to attract all the existing first class traffic from the subsonic jets, where the two types are operated together, and to attract a significant proportion of the business traffic which currently takes advantage of promotional fares on subsonic aircraft. There are numerous business and other passengers who can afford to pay the first class fare but who do not consider the increased cost to be justified. However, it is a reasonable assumption that if these travellers can have the benefit of halved journey times, many of them will be prepared to pay the premium fare.

Configured to this new concept Concorde will be operated in a 108-seat layout with four-abreast seats at 38 inches pitch between seat rows with generous passenger amenities.



'Superior Class' (108-seat) passenger accommodation plan.

Operating Economics

According to the manufacturers, Concorde can be as profitable in operation as the Boeing 747. Recent detailed analysis of four key routes (Paris-New York; Paris-Tokyo; London-Johannesburg; and London-Sydney)—has shown that the break-even payload factors of the Concorde can be expected to be below 50 per cent and better than or equal to those of the 747.

Despite its substantially higher unit operating costs it is held that the Concorde can therefore be used on suitable routes at a level of profitability as high as or higher than that achieved by the 747.

In this respect, it is relevant to note—the makers say—that, whereas the Jumbo has to win around 165 passengers on every flight in the extremely intensive and diverse competition from the charter companies at the cheaper end of the market in order to break even, Concorde needs only 50 or less high-fare (regular) travellers to cover its costs.

First Customer Orders

Initiation of the first firm orders for Concorde was greatly facilitated when the initial pricing formula was announced in December 1971—a base price of around £13 million per aircraft.

This led to the most important event in the entire Concorde programme which occurred on July 28 1972—BOAC and Air France signed the first firm commercial contracts for five and four Concordes respectively. The Peoples Republic of China had signed a preliminary purchase agreement for two Concordes four days early and added a third a month later. Following an initial declaration of intent by the Shah of Persia at the time of the visit of Concorde 002 to Tehran in June, Iranair also signed a preliminary purchase agreement for two Concordes in October 1972.

However, the much hoped-for conversion of options into firm contracts by the key American operators Pan American and TWA at the end of January 1973 did not materialise. Though obviously a setback, the confidence of the manufacturers and the British and French governments was undiminished and firm resolve was expressed to maintain the planned date of January 1975 for the achievement of the Certificate of Airworthiness to enable BOAC and Air France to inaugurate service during that year.

30 Year Programme

Of the long-term future of Concorde Sir George Edwards said: 'The thing that lays before us is to get this programme on a proper and sensible

Latest standard passenger cabin styling in the full-scale Concorde mock-up at Filton.

even keel so that at the end of it there is a lot of Concordes. We must keep going until the airlines who are currently turning their backs on Concorde realise they can't afford to do so any longer. In this way we can build up to the big 30 year programme I have always envisaged the Concorde as having.

Concorde will show that the combination of standards of comfort and saving in time will make it attractive to customers. I think the operating costs are getting firmer and firmer every day and are costs which will enable the aircraft to be operated on the North Atlantic and other world routes on a profitable basis' Sir George said.

Intensive market negotiations continue throughout the world.

Inauguration of the Supersonic Age of Air Travel

Concorde will thus begin service during 1975 on the key international routes of BOAC and Air France.

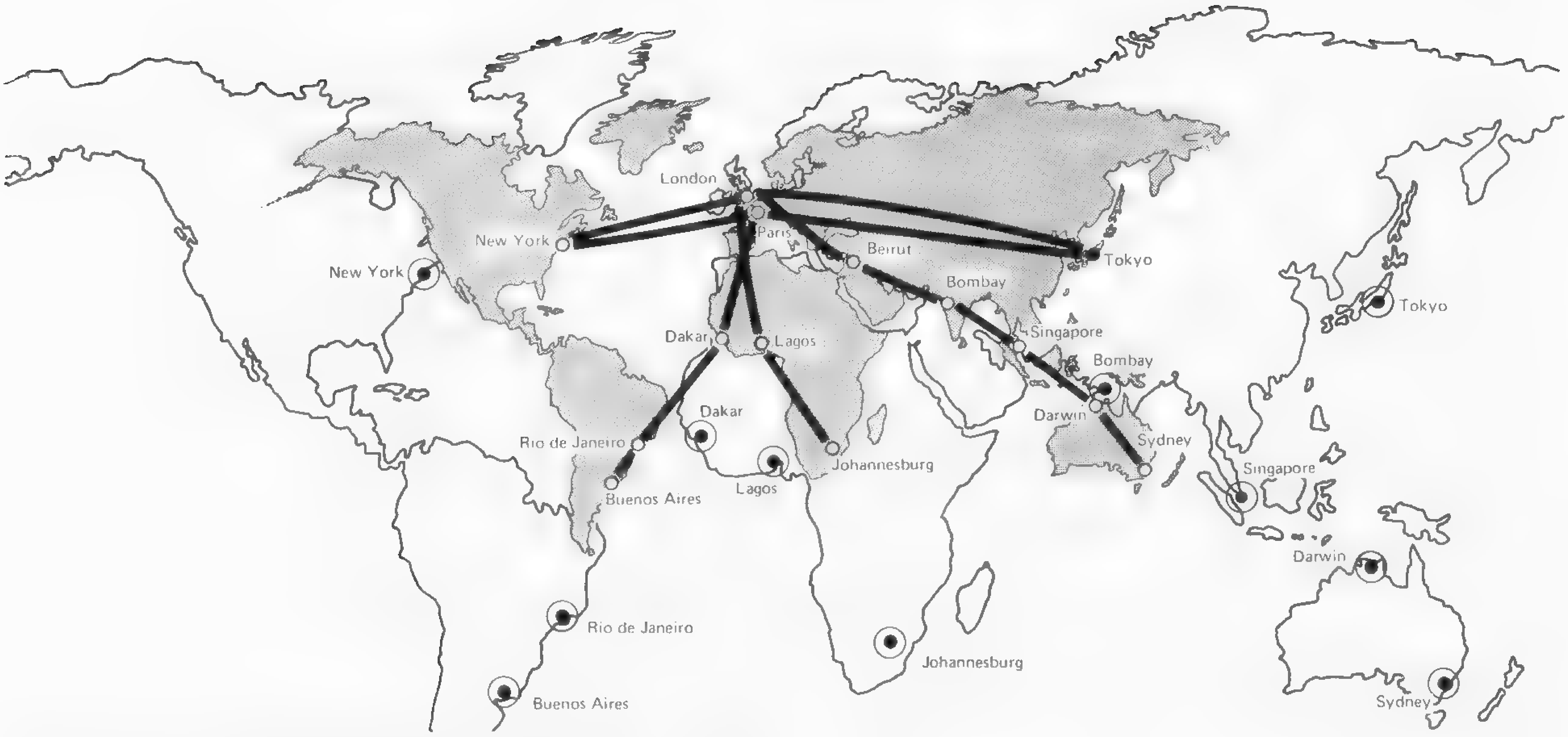
BOAC's initial Concorde schedules are expected to be: twice daily between London and New York, three times a week between London and Sydney and between London and Johannesburg, and twice a week between London and Japan.

At the same time, Air France plans to begin Concorde services on the Paris-New York route twice weekly, Paris-Buenos Aires six times weekly, and the Trans-Siberian Paris-Tokyo route twice weekly.

The Civil Aviation Administration of China says that Concorde could cut the present journey time between Peking and Paris from around 20 hours to only 8 hours.

Product Support

To match the needs of these global operations,



The new dimensions of the world with supersonic speeds and halved journey times.

a big and comprehensive product support organisation is already well advanced in the planning stage—through the joint BAC/Aérospatiale Concorde Support Division (CSD) and the Rolls-Royce/SNECMA Concorde Engine Support Organisation (CESO).

Environmental Factors

Concorde's manufacturers are convinced that the benefits of supersonic transport can be achieved without excessive pollution of the environment or disadvantage to society in general.

Concern about the possible impact of SSTs on the environment has been expressed in three main areas: High Altitude Effects, Pollution and Noise.

High Altitude

It has been suggested that supersonic operations in the stratosphere could cause serious disturbance to the natural balance and structure of the atmosphere and so produce considerable changes in the earth's climate. Some scientists have made pessimistic forecasts, based on extreme assumptions, about the possible effects of SST operations on the ozone layer which protects the earth against ultraviolet light. These forecasts have been refuted by scientists of equally eminent standing, and the fact that there is already a great volume of aircraft operation, both supersonic and subsonic, in the stratosphere which has produced no discernible adverse effects on the climate. The manufacturers' conviction is (and this is shared by many responsible scientists) that, analysed scientifically and mathematically rather than emotionally, there is little evidence to support the forecasts of adverse effects in the stratosphere and that monitoring will, in any event, they claim, provide an absolute safeguard.

Pollution

It has also been suggested that the ozone layer would be destroyed by the oxides of nitrogen from jet engine exhaust of high flying supersonic aircraft. To this charge the manufacturers say that it will be impossible to detect the variation of the ozone amount so caused within the naturally occurring variation which can be of the order of 10 per cent over a period as short as a few days.

They also point out that despite periodic injections of oxides of nitrogen by nuclear weapon tests and the increasing volume of stratospheric operation by commercial subsonics and military supersonics, the amount of ozone in the stratosphere as measured at several stations around the world had been steadily increasing, in some cases, by more than $\frac{1}{2}$ per cent per year.

Radiobiological risks associated with exposure to cosmic radiation at high altitudes are believed to be extremely remote, but Concorde will still carry special warning equipment—although the total risk both in supersonic and subsonic aircraft is said to be only one-thirtieth the risk of death by aircraft accident.

Noise and the Sonic Boom

Concorde's airfield noise on entry into service will be of the same order as that of current subsonic jets—such as the Boeing 707 and the McDonnell Douglas DC-8—large numbers of which will continue in front-line service for many years after Concorde's introduction.

Concorde has already demonstrated that it can operate into and out of existing airports without special attention. The manufacturers have a major long-term research programme in hand to effect further reductions of Concorde noise levels.

The 'sonic boom' phenomenon is the principal new problem associated with supersonic

transport operation. The intensity of the boom depends mainly on two factors: the weight at which the aircraft is flying and its altitude. The heavier the aircraft, the greater the intensity of the boom that it is capable of generating. The higher it is flying, the more the boom will be attenuated by the time the sound pressure wave reaches the ground.

Evidence so far is that Concorde's sonic boom is unlikely to cause physical damage, nor will it cause material damage to any reasonably well-maintained structure. Whether or not the boom is socially acceptable will be a decision by Governments, taken in the light of public opinion. Concorde's manufacturers have always assumed, in their market research, that supersonic flight would only be permitted over the oceans and overland by national governments over areas of sparse population and the large and uninhabited deserts which form a considerable element of the earths surface. In this context it is significant that between 74 and 80 per cent of todays intercontinental seat-miles are, in fact, flown over the sea.

The Cost/Benefit Equation

The R. & D. Bill

The main area in which Concorde continues to be called into question is that of launching costs—how what was estimated to be £150-£170 million in 1962 has grown to £970 million in 1972 (shared equally by Britain and France).

The notional research and development (R. & D.) cost estimate of 1962 was made in complete absence of knowledge of the very demanding technology that has since become necessary, with no relevant datum for cost prediction, and was in the *prevailing monetary values and took no account of inevitable escalation*.

Although this figure has apparently escalated by £800 million, more than half of this growth—around £430 million—is due to progressive monetary inflation, which has averaged 7½ per cent per annum over the intervening 10 years—together with two devaluations of the British Pound and one of the French Franc—all completely beyond the control of the manufacturers.

Additionally, substantial extra work has become necessary as the programme has been progressively defined in the light of evolving airline requirements—none of which could have been foreseen in 1962. This accounts for around £180 million in 1972 terms. It has been due to several major factors—notably post-certification development (£80 million), general contingencies (£50 million) and, of course, the incorporation of substantial technical development (both airframe and engine) through three successive build standards—the initial prototypes, the pre-production and series production models—that have been made necessary by the developing requirements of the airlines and airworthiness authorities and the greater length of time needed to achieve the Certificate of Airworthiness, none of which were anticipated in the original estimate.

To set the ultimate figure of £970 million in perspective it is worth noting that a recent US Government paper has disclosed that development of the Boeing 747 airframe cost the equivalent of £500 million and the McDonnell Douglas DC-10 £450 million, to which in both cases has to be added something between £150-200 million for development of the engines. Both these programmes were straightforward extensions of existing technology and both were completed in correspondingly shorter time scales and under a single design authority. Concorde programme costs for research and development are thus not as excessive as may at first be supposed.

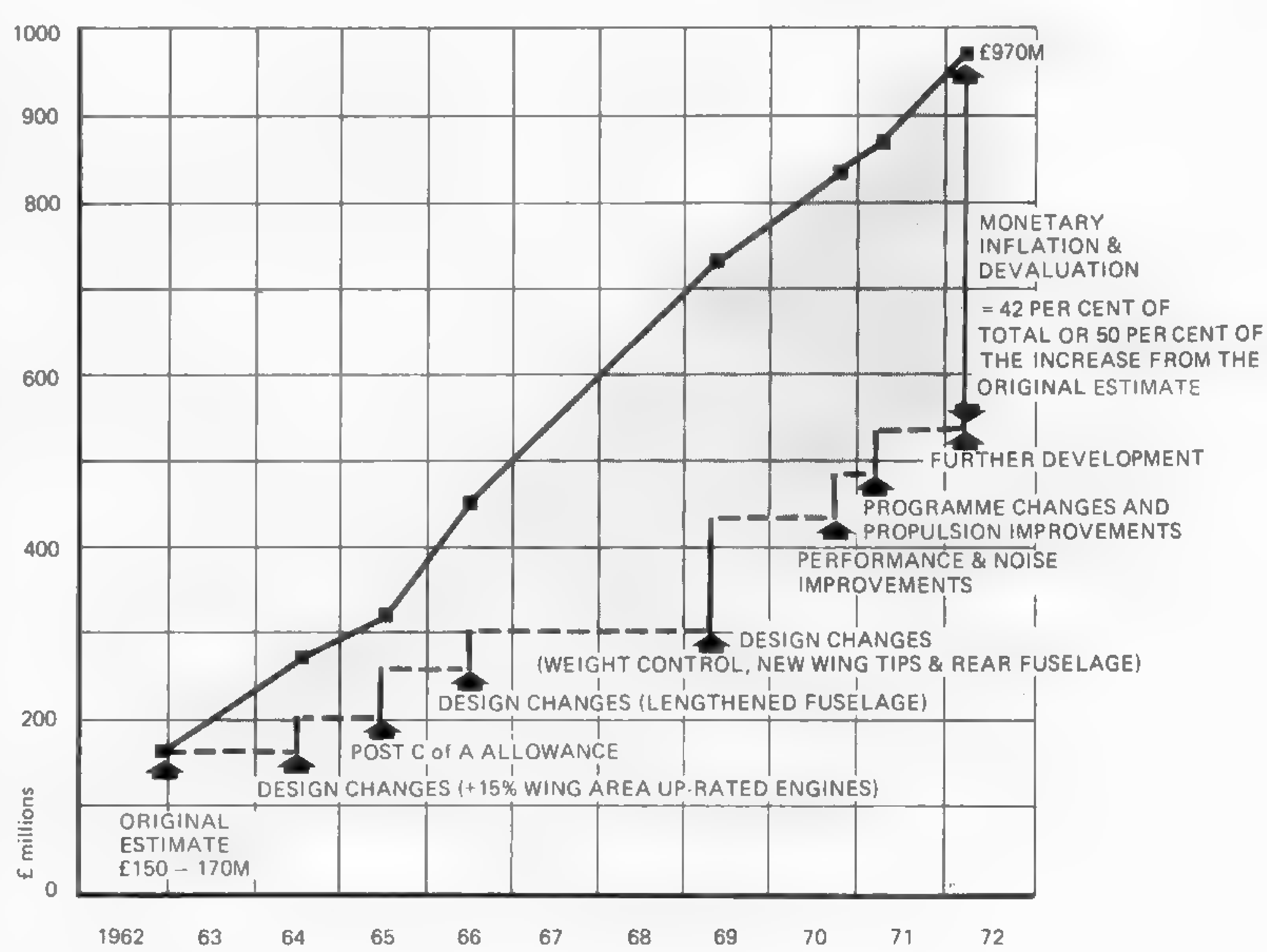
The USA is reported as having spent £365 million on its abortive supersonic airliner project (and a further £280 million in cancellation penalties and the various human resources costs resulting therefrom).

What it Buys

The £970 million R. and D. funds for Concorde cover:

- Design and construction of two prototypes 001 and 002;
- Design and construction of two pre-production aircraft 01 and 02;
- Construction of two airframe specimens and other major components for static and fatigue testing;
- The static and fatigue test programmes;
- The flight development programmes, shared by the two prototypes, two pre-production and the first three production aircraft and leading to award of a certificate of airworthiness;

Concorde programme development costs.



- Initial production tooling;
- Continued development after C. of A.;
- Design and development of a new engine through successively more powerful marks, and of a new rear nozzle for commercial supersonic operation.
- The build of 63 Rolls-Royce Olympus engines for ground and flight testing;
- Design, development and tooling of a new range of aircraft equipment for commercial supersonic operation;
- A complete range of ground handling and test equipment.

(While use of the first three production aircraft for flight development is an R. and D. cost their actual construction is a production charge.)

Production Loans

Financing of Concorde production work-in-progress is quite separate from the basic 'non-recurring' R. and D. charges and is being covered by interest-bearing bridging loans from the two Governments to cover the period when outgoings in wages and materials are high before income, in the form of progress payments from customers, begins.

To meet this need the British Government authorised in February 1968 a sum of £125 million to launch production of aircraft and engines which was made up of loans from public funds, plus bank loans guaranteed by the Government. This was increased to £250 million in March 1973—with the provision for a further £100 million later as required. Similar arrangements are being made by the French Government. These loans will be wholly repaid from the proceeds of sales.

In summary, the £970 million R. and D. finance is for the creation of a fully tested and certificated aircraft, an element of which is to be repaid by sales levies. The production finance is a straight loan transaction bearing the going rate of interest to be repaid as the manufacturers deliver the completed aircraft and get paid for them.

There is also provision for the supply via HMG of certain special tools and plant to a value of about £30 million to BAC and Rolls-Royce and for which an appropriate rental is charged.

The Benefits

The Concorde R. and D. expenditure is regarded by Britain and France as an investment for the future.

The purely financial benefit readily estimated is Concorde's contribution to the balance of payments: BAC and Aérospatiale's expectation of sales of up to 200 Concordes by the beginning of the 1980s will result in a contribution to the trade balance over the operational life of these aircraft of the order of £4,000 million of the exchequer of Britain and France. When, in addition to this, account is taken of the sales and operation of potential Concorde derivatives up to at least the end of the present century, the size of the investment and the immense resulting benefits can be seen in true perspective.

Concordes effect on the British and French national economies is to create substantial and sustained employment, and hence tax repayments, to provide an immense modernising force across a wide range of industries and geographical areas. At the same time input-output studies of these economies have demonstrated clearly that such an outlay in high technology industry has a greater overall growth effect than does investment in less sophisticated areas. This arises principally because of the dominating element of payment for brainpower and skills rather than imported raw materials—in a 90/10 ratio.

This stimulation has already spread to many new products and processes. A survey shows that around 70 per cent of the 600 odd British firms contributing to Concorde have admitted to material benefits from the programme. These range from improved management procedures through to new products and capabilities, all of which mean that they are better able to produce, market and export their goods—another item which should be entered in the Concorde 'credit ledger'.

The scope of the returns in terms of new manufacturing techniques and processes and technological advance throughout industry are claimed to be inestimable.

In this respect there is clear evidence that the great advances in the use of numerically controlled machine tools and in electro-chemical machining has been largely stimulated by work on Concorde. There are also comparable advances in manufacturing techniques, such as electron-beam welding and the use of laser beams in the working of titanium.

Again, the materials and precision and medical equipment industries have benefited substantially from research and development initiated specifically for Concorde—such as titanium, plastics, glass, lubricants, paints, seals and plumbing techniques, miniaturisation, electric motors and actuators, brakes and anti-skid devices, and thermal controls.

Scientific and data processing computer techniques which have accrued from Concorde design and production are acknowledged as industry-leading in Europe.

Finally, it is pointed out that expensive as the Concorde programme obviously is, there is no other basis for true comparison—nothing is known of the development costs of the Russian Tu-144—and the ultimate aircraft is substantially better all round than its original conception.

The Way Ahead

Concorde is Europe's proudest airliner achievement and the world's fastest. Its ability to halve

international journey times at a stroke, coupled with its uniquely distinctive visual appeal, will enable it to introduce a completely new concept of air travel and the greatest advance in the history of air transport.

The spearheading concept of Concorde has lifted transport aircraft technology to a new plateau—and has crossed the sonic and heat barriers in one leap. In turn, it will stimulate exciting new horizons in future generations of air transport development throughout the world.

Todays aircraft represents only the first of the inevitable development stages in size and range which will be achieved as Concorde matures to fulfill its enormous potential in a wide range of roles and its concept is unlikely to be outmoded in this century.

As Sir George Edwards points out:

'We read much of a second-generation supersonic transport, often in the context of a super-giant Mach 3 plus aeroplane which would sweep the Concordes out of the sky.

'The expense and long development time which would be needed to replace the now defunct US SST suggests that the right course to follow is that of steady development based on what we already have and know about. As with all successful designs, I see Concorde following the standard procedure of stretch—range and capacity—which will result from improvements already more than a twinkle in the eye.

'The second generation SST will almost certainly look and fly like a Concorde although geometrically it may be scaled up here and there.

'In Concorde we have found an elegant solution to the problem of efficient supersonic flight and any immediate successor which might appear within the century will, I feel certain, bear the same family relationship to Concorde as the Boeing 747 bears to the 707—the same format, but not much faster.

'The ultimate replacement of the Concorde on the very long-haul routes may well arrive as a spin-off from the Space Shuttle programme rather than as an extension of any aircraft family tree.

'Certainly the plan for the years ahead must be to sell what we have to offer—a first class product with built-in stretch.'

Concorde—Worldshrinker

While Concorde continues to have its dissenters, conjecture is steadily being supplanted by fact and demonstration as it faces up to its real judges—the worlds airlines and their ever-discerning passengers, the sole arbiters of air transport progress.

The thoroughbred consolidation of unmatched experience, research and development, Concorde should well justify its significance and its newest accolade 'The Worldshrinker' through into the hypersonic era. Soon passengers will have the opportunity to prove it.

Concorde's famous pilots: (left) André Turcat, Director of Flight Test of Aérospatiale, and (right) Brian Trubshaw, Director of Flight Test of the BAC Commercial Aircraft Division—seen together on the flightdeck of Concorde 002 at Toulouse.

Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the French Republic regarding the development and production of a civil supersonic transport aircraft

London, November 29 1962

The Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the French Republic;

Having decided to develop and produce jointly a civil supersonic transport aircraft;

Have agreed as follows:

Article 1

(1) The principle of this collaboration shall be the equal sharing between the two countries, on the basis of equal responsibility for the project as a whole, of the work, of the expenditure incurred by the two Governments, and of the proceeds of sales.

(2) This principle, which shall be observed as strictly as possible, shall apply, as regards both development and production (including spares), to the project considered as a whole (airframe, engine, systems and equipments).

(3) The sharing shall be based upon the expenditure corresponding to the work carried out in each country, excluding taxes to be specified by agreement between the two Governments. Such expenditure shall be calculated from the date of the present Agreement.

Article 2

The two Governments, having taken note of the agreement dated 25th October, 1962 between Sud Aviation and the British Aircraft Corporation (BAC) and of the agreement dated 28th November, 1961 between Bristol Siddeley and the Société Nationale d'Etudes et de Construction de Moteurs d'Aviation (SNECMA) have approved them, except in so far as they may be in conflict with provisions which are the subject of agreement between the Governments.

Article 3

(1) The technical proposals, which shall form the basis for the joint undertaking by Sud Aviation and BAC comprise a medium range and a long range version of the aircraft.

(2) The Bristol Siddeley-SNECMA BS593/3 turbojet engine shall be developed jointly for the aircraft by Bristol Siddeley on the British side and by SNECMA on the French side.

Article 4

In order to carry out the project, integrated organisations of the airframe and engine firms shall be set up.

Article 5

A Standing Committee of officials from the two countries shall supervise the progress of the work, report to the Governments and propose the necessary measures to ensure the carrying out of the programme.

Article 6

Every effort shall be made to ensure that the programme is carried out, both for the airframe and for the engine, with equal attention to the medium range and the long range versions. It shall be for the two integrated organisations of the British and French firms to make detailed proposals for the carrying out of the programme.

Article 7

The present Agreement shall enter into force on the date of its signature.

In witness whereof the under-signed, being duly authorised thereto by their respective Governments, have signed the present Agreement.

Done in duplicate at London this 29th day of November 1962 in the English and French languages, both texts being equally authoritative.

For the Government of the United Kingdom of Great Britain and Northern Ireland:

JULIAN AMERY
PETER THOMAS

For the Government of the French Republic:

G. de COURCEL

LEADING PARTICULARS AND TECHNICAL DESCRIPTION

The following data and description applies to the intial production Concorde:

Aircraft Type: Supersonic transport airliner.

External Dimensions: Wing span 83 ft. 10 in. (25.56 m.); Overall length 203 ft. 9 in. (61.66 m.); Overall height—at Operating Empty Weight 37 ft. 1 in. (11.32 m.); Main wheel track 25 ft. 4 in. (7.72 m.); Wheelbase 59 ft. 8 in. (18.19 m.).

Areas: Wings, gross 3,856 sq. ft. (358.25 m.^{2}); Aspect ratio 1.7; Elevons (total) 344.44 sq. ft. (32.00 m.^{2}); Fin (less dorsal) 365 sq. ft. (33.91 m.^{2}); Rudder 112 sq. ft. (10.4 m.^{2}).

Weights and Loadings: Maximum Taxi Weight 393,000 lb. (178,260 kg.); Maximum Take-off Weight 389,000 lb. (176,450 kg.); Maximum Landing Weight 245,000 lb. (111,130 kg.); Maximum Zero Fuel Weight 203,000 lb. (92,080 kg.); Typical Payload 25,000 lb. (11,340 kg.); Basic Operating Weight 172,500 lb. (78,245 kg.); Fuel Capacity 206,000 lb. (93,440 kg.); Max. wing loading approx. 100 lb./sq. ft. (488 kg./m.^{2}); Max. power loading approx. 2.5 lb./lb. st (2.5 kg./kg. st).

Performance: Estimated at Max T-O Weight: Minimum airborne speed 200 knots (230 m.p.h.; 370 km./h.); Cruise altitudes 50,000-60,000 ft. (15,240-18,290 m.); Max. cruising speed at 51,300 ft. (15,640 m.) Mach 2 or 530 knots CAS, whichever is the lesser—equivalent to TAS of 1,130 knots (1,300 m.p.h.; 2,032 km./h.); Max. range speed approx. Mach 2.05; Rate of climb at SL 5,000 ft. (1,525 m.)/min.; Service ceiling approx. 60,000 ft. (18.290 m.); T-O to 35 ft. (10.7 m.) 10,050 ft. (3,063 m.); Landing from 35 ft. (10.7 m.) 7,980 ft. (2,432 m.); Range with max. fuel, FAR reserves, and 12,500 lb. (5,670 kg.) payload: 3,750 n.m. (4,313 miles; 6,936 km.); Range with max. payload, FAR reserves: at Mach 0.93 at 30,000 ft. (9,100 m.) 2,650 n.m. (3,050 miles; 4,900 km.); at Mach 2.05 cruise/climb 3,350 n.m. (3,853 miles; 6,196 km.); Min. ground turning radius 63 ft. 6 in. (19.35 m.); LCN at max. T-O weight 89.

Operational Noise Characteristics: Take-off: (flyover) 3.5 n.m. (4 miles; 6.5 km.) from start of T-O roll 114 EPNdb; Approach: at 1 n.m. (1.15 miles; 1.85 km.) from landing threshold on 3° glide-slope 115 EPNdB; Sideline: 0.35 n.m. (0.40 miles; 0.65 km.) from runway c/l 111 EPNdB.

Powerplants: Four Rolls-Royce/SNECMA Olympus 593 Mk.602 axial flow two-spool turbojets plus partial reheat—with thrust reversers and silencers.

Performance Rating: Nominal take-off thrust, S.L. static, reheat 'On' 38,050 lb. (17,260 kg.); Cruise thrust (60,000', ISA+5°C M=2.0) 6,791 lb. (3,080 kg.); Cruise fuel consumption (lb./lb. thrust/hour) 1,189; Cruise engine pressure ratio 11.6:1.

Dimensions: Max. diameter at intake 47.75 in. (121.3 cm.); Length, flange-to-flange nozzle 154 in. (391 cm.); Intake flange to final nozzle 273 in. (693 cm.).

Weight: Basic, dry, 'undressed' 6,090 lb. (2,762 kg.).

Air Intake: Each Olympus engine installed downstream of intake duct incorporating auxiliary intake and exit door systems and a throat of variable profile and cross-section.

Compressors: Seven-stage axial-flow LP and HP compressors.

Turbines: Single-stage air-cooled co-axial HP and LP turbines.

Exhaust System: New design thrust reverser and secondary nozzle known as TRA (thrust-reverser aft) based on use of reverser buckets as both reverser and secondary nozzle for noise attenuation.

Accessory Drives: Two gearboxes beneath compressor intermediate casing, both mechanically driven off HP shaft. LH gearbox drives main engine oil pressure/scavenge pumps and the first-stage fuel pump. RH gearbox drives aircraft hydraulic pumps and CSD/alternator.

Fuel System: Mechanically driven first-stage pump with second-stage pump driven by air turbine shut down at cruise when fuel requirements can be met by first-stage pump alone. The first-stage pump also supplies reheat fuel. Fuel cooled air-cooler incorporated. Electronic system, with integrated-circuit amplifier, provides combined control of fuel flow and primary nozzle-area. Electrically controlled reheat fuel system.

Lubrication System: Closed-type using oil to specification DERD 2497, MIL-L-9230B. Pressure pump, multiple scavenge pumps, and return through fuel/oil heat exchanger.

Starting System: Air-turbine driving HP spool. Dual high-energy ignition system serves igniters in annular chamber.

Mounting: Main expansion type trunnions on horizontal centreline of delivery casing. Front stay from nacelle roof locates on top of intake casing.

Accommodation: Flight Crew: Pilot and co-pilot side-by-side on flight deck, with third crew member behind on starboard side at systems management panel. Provision for supernumerary seat behind pilots Cabin Layout: Wide variety of four-abreast seating layouts to suit individual airline requirements: Typically: Superior Class—108 at 38 in. (96.5 cm.) pitch. Standard Class—128 at 34 in. (86 cm.) pitch (with full galley and toilet facilities.) Maximum—144 at 32 in. (81 cm.) pitch. Two gallery areas. Toilets at centre and/or rear. Baggage space under forward cabin and aft of passenger cabin. Passenger doors forward and amidships on port side, with service doors opposite. Baggage door aft on starboard side. Emergency exits in rear half of cabin on each side.

Internal Dimensions: Cabin: Length (flight deck door to rear pressure bulkhead, including galley and toilets) 115 ft. (35.04 m.); Width—external 9 ft. 5 in. (2.9 m.); Width—internal 8 ft. 7½ in. (2.63 cm.); Aisle Width 17 in. (0.43 m.); Height 6 ft. 5 in. (1.96 m.); Volume 8,440 cu. ft. (238.5 m^2); Window size 6.3 in. × 4 in. (16 cm. × 10 cm.); Window spacing approx. 20 in. (50.8 m.); *Passenger doors (each): Height 5 ft. 6 in. (1.68 m.); Width 2 ft. 6 in. (0.76 m.); Sill height: fwd. 16 ft. 3 in. (4.96 m.), amidships 15 ft. 7 in. (4.74 m.), *All doors 'Type 1' Emergency Exits; Baggage/freight compartments: Underfloor 227 cu. ft. (6.43 m^3.); Rear fuselage 470 cu. ft. (13.3 m^3.) Total 697 cu. ft. (19.74 m^3.); Baggage hold door (underfloor): Length 3 ft. 3 in. (0.99 m.); Width 2 ft. 9 in. (0.84 m.); Sill Height 11 ft. 7 in. (3.33 m.); Baggage hold door (rear, stbd.): Height 5 ft. 0 in. (1.52 m.); Width 2 ft. 6 in. (0.76 m.); Sill Height 12 ft. 11 in. (3.94 m.).

Airframe:
Wings: Cantilever low wing of ogival delta planform. Thickness/chord ratio 3 per cent at root, 2.15 per cent from nacelle outboard: Slight anhedral. Continuous camber. Multi-spar torsion-box structure, manufactured mainly from RR58 (AU2GN) aluminium alloy. Integral machining used for highly loaded members and skin panels.

Three elevons on trailing-edge of each wing, of aluminium alloy honeycomb construction each independently operated by a tandem jack, each half elevon being supplied from an independent hydraulic source and controlled by a separate electrical system and auto-stabilisation provided. Autopilot control by signals fed into normal control circuit. No high-lift devices. (Air-brakes on prototypes only). Leading-edges ahead of air intakes electrically de-iced.

Fuselage: Pressurised aluminium alloy semi-monocoque structure of oval cross-section, with unpressurised nose and tail cones. Hoop frames at approx. 21.5 in. (0.55 m.) pitch support mainly integrally-machined panels having closely-pitched longitudinal stringers. Nose section droops hydraulically to improve forward view during take-off, initial climb, approach and landing. Retractable visor raised hydraulically to fair in pilots windows in cruising flight.

Empennage: Vertical fin and rudder—no tailplane. Fin—multi-spar torsion box of similar construction to wing. Aerodynamic reference chord at base 84 ft. 9 in. (10.59 m.). Two-section honeycomb rudder controlled as elevons. No de-icing.

Landing Gear: Hydraulically-retractable tricycle type. Retractable tail wheel. Four-wheel bogie main units retract inward. Twin-wheel steerable nose unit retracts forward. Oleo-pneumatic shock absorbers. Main wheel tyres (eight) 47 × 15.75–22, pressure 184 lb./sq. in. (12.9 kg./cm^2.). Segmented disc brakes and anti-skid units. Nosewheel tyres two /31 × 10.75–14, pressure 174 lb./sq. in. (12.25 kg./cm^2.).

Engine Nacelles: Each consists of hydraulically-controlled ramp variable-area air intake, engine bay and nozzle support structure. Intakes of aluminium alloy with steel leading-edges. Engine bay has 'Inconel' centre wall with aluminium alloy forward doors and titanium rear doors. Nozzle bay, aft of rear spar, of welded 'Stresskin' sandwich panels and heat-resistant nickel alloys. Thrust reverser buckets—also used as secondary nozzle. Eight equi-spaced retractable spade silencers actuated by pneumatically-operated ball-screws driven through flexible shafts. Leading-edges of intake walls, rear ramp sections and intake auxiliary doors de-iced by engine bleed air.

Systems:
Fuel: Also used as heat sink and as a means of maintaining aircraft trim.

All tanks of integral construction and arranged in two groups. Main tank group comprises five compartments in each wing and four in the fuselage and is arranged to maintain aircraft centre of gravity automatically in cruising flight. Trim tank group—three—comprises two tanks in the wings and one of 2,800 Imp. gallons (12,730 litres) capacity in fuselage beneath fin. This group maintains correct relationship between CG and aerodynamic centre of pressure by transferring fuel rearward during transonic acceleration and forward during return to subsonic flight. Four pressure refuelling points in underwing fairing—two forward of each main landing gear unit.

Engine Oil: Capacity 3.0 Imp. gallons (13.6 litres) per engine. Oil for CSD in separate tank-capacity 0.75 IG (3.4 litres).

Pressurisation/Air Conditioning: Comprises four independent sub-systems with heat exchangers. Cabin working pressure differential 10.7 lb./sq. in. (0.75 kg./cm^2.). In each sub-system the air passes through primary ram-air heat exchanger to air cycle cold-air unit, and then through secondary air/air and air/fuel heat exchangers. Air then mixed with hot air and fed to passenger cabin, flightdeck, baggage holds, landing gear, equipment and radar bays.

Hydraulic: Two primary and one standby system Pressure 4,000 lb./sq. in. (280 kg./cm^2.) each actuated by two engine-driven pumps. Oronite M2V fluid temperature limited by heat exchangers. Main systems actuates flying control surfaces, artificial feel units, landing gear, wheel brakes, nosewheel steering, pilots visor, droop nose engine intake ramps, and fuel pumps in rear transfer tank.

Electrical: System powered by four 60 kVA engine-driven constant-speed brushless alternators giving 200/115V AC at 400 Hz. Four 150 A transformer-rectifiers and two 25 Ah. batteries provide 28V DC supply.

Electronics: Primary navigation system comprises three identical inertial platforms (each coupled to digital computer to form three self-contained units), two VOR/ILS systems, one ADF, two DME, one marker, two weather radars and two radio altimeters. Provision for supplementary system including long-distance radio fixing system of the Loran 'C' type. Optional equipment includes second ADF. Basic communications equipment consists of two VHF and two HF transmitter/receivers, one Selcal decoder and two ATC transponders. Provision for third VHF transmitter/receiver and data link equipment.

All-Weather Operation: Duplicated autopilots, autothrottles and the above navigation systems will enable certification to Category II all-weather landing minima at entry into service and Category IIIA automatic landing when sufficient flight experience accumulated. Provision also made to accommodate automatic chart display and area navigation when standards for this type of equipment finalised.

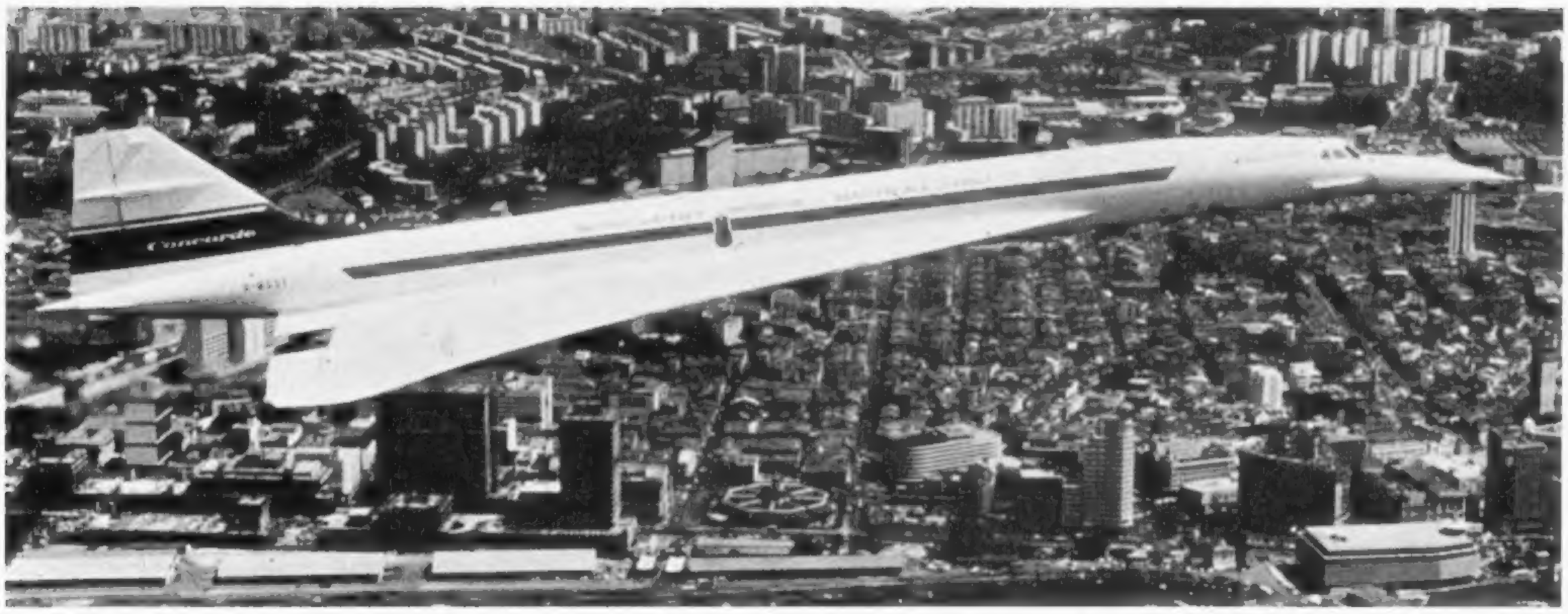
CONCORDE 002 SALES TOUR—1972

Middle, Far East and Australian Sales Demonstration Tour, 2 June to 1 July 1972.

Distance flown: 45,000 miles (72,500 Km.)
Twelve countries visited: Twenty sectors flown through Greece; Iran; Bahrain; India; Burma; Singapore; Philippines; Japan; Australia; Saudi Arabia; Lebanon and France.

Flights:	32—25 supersonic; 13 demonstration
Total Flying time	62 hrs.
Block time	70 hrs. 20 mins.
Supersonic time	23 hrs. 10 mins.
Supersonic time at Mach 2	13 hrs. 40 mins.
En-route time	43 hrs.
Demonstrations	19 hrs.
Concorde 002 total journey time	40 hrs. 45 mins.
Scheduled subsonic time	65 hrs.
Engine flight time:	252 hrs. 92 hrs. supersonic
VIP passengers included:	One Head of State 14 Ministers 12 Airline Chiefs
Seen by airport crowds:	Over 300,000 (estimated)

London—Heathrow static display 1–5 July witnessed by an estimated 50,000 people.



Concorde 002 seen over Singapore during its 45,000-mile sales demonstration tour of the Middle and Far East and Australia in June 1972.

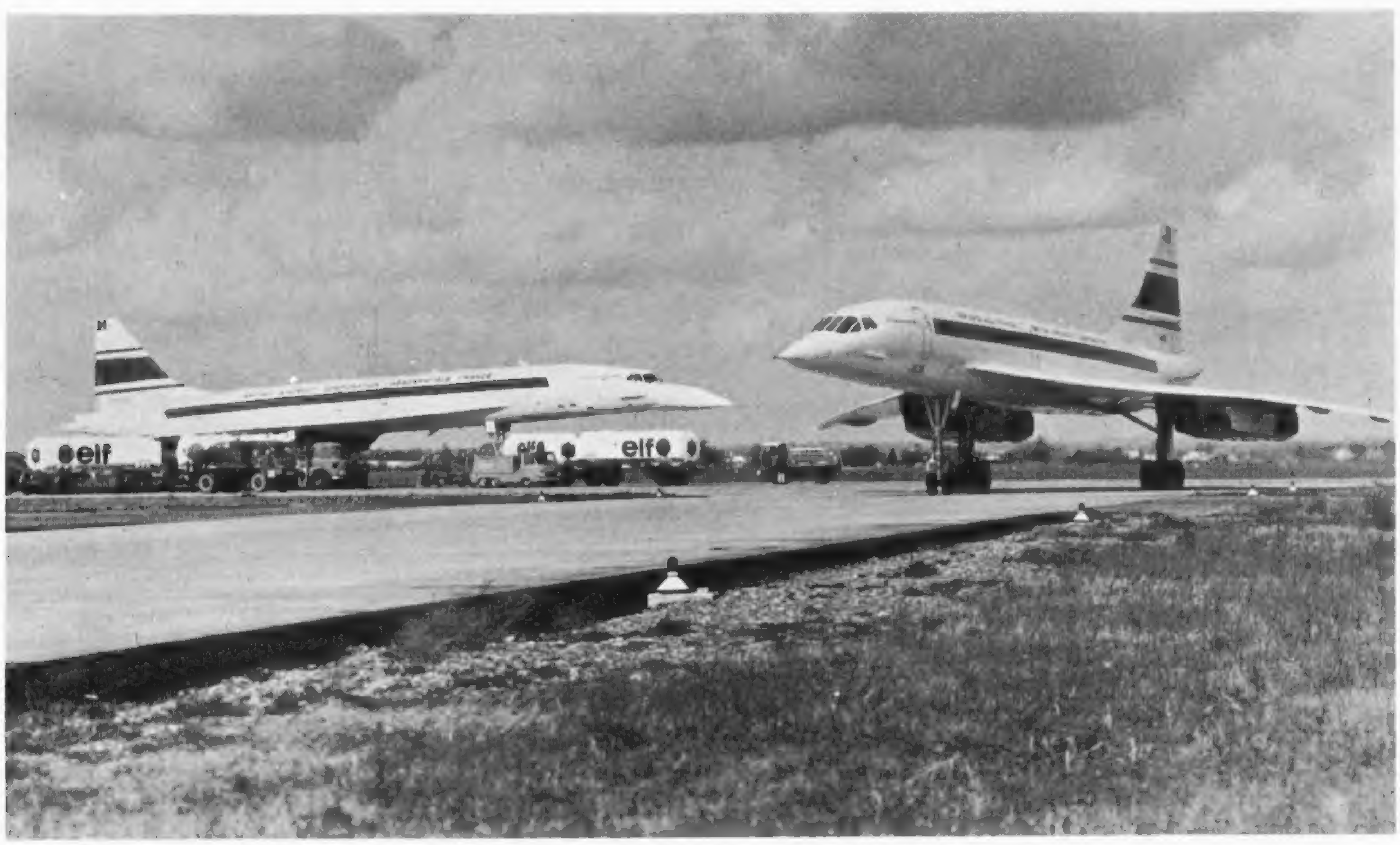
Concorde Chronology

1956	Basic supersonic airliner research starts in Britain and France.
November 5 1956	British Supersonic Transport Aircraft Committee (STAC) first meets.
1959–1961	SST feasibility and design studies in Britain and France.
1961–1962	Preliminary Anglo-French discussions on commonality of SST requirements and design studies, leading on to investigation of possible collaboration.
1961	First discussions between BAC and Sud
June 8 1961	Aviation—Paris.
July 10 1961	—Weybridge.
November 29 1962	British and French Governments sign Agreement for joint design, development and manufacture of a supersonic airliner.
1963	Preliminary design for 100-seat SST discussed with key airlines.
May 1963	First metal cut for test specimens.
June 3 1963	First Concorde sales option signed by Pan American.
June 1963	BOAC and Air France sign Concorde sales options.
May 1964	Announcement of developed aircraft (at IATA Technical Committee Meeting in Beirut) with increased wing area and lengthened fuselage providing accommodation for up to 118 passengers—the design subsequently 'frozen' for prototype manufacture.
July 1964	Olympus 593 'D' (Derivative) engine first run at Bristol, England.
April 1965	First metal cut for Concorde prototypes.
May 1965	Pre-production Concorde design (130 seats) announced.
October 1965	Prototype Concorde sub-assemblies started.
November 1965	Olympus 593 'B' (Big) engine first run at Bristol.
March 1966	Sixteen-ton centre fuselage/wing section for static and thermal testing delivered to CEAT, Toulouse, France.
April 1966	Final assembly of Concorde prototype 001 begins at Toulouse.
June 1966	Concorde main flight simulator commissioned at Toulouse.
June 1966	Complete Olympus 593 engine and variable geometry exhaust assembly first test-bed run at Melun-Villaroche, France.
August 1966	Final assembly of Concorde prototype 002 begins at Filton (Bristol), England.
September 1966	Vulcan flying testbed with Olympus 593 makes first flight.
September 1966	Olympus 593 first run in Cell 3 high altitude facility, NGTE Pyestock, England.
October 1966	Olympus 593 achieves 35,190 lbs. (dry) thrust on test at Bristol, exceeding 'Stage 1' brochure requirement.
December 1966	Seventy-foot long fuselage and nose section delivered to RAE Farnborough for fatigue testing.
1966	Detailed and continuing discussions begin on all aspects of Concorde development between manufacturers and specialist engineering committees representing all customer airlines.
February 1967	Full-scale Concorde interior mock-up at Filton first presented to customer airlines.
April 1967	Complete Olympus 593 engine first test-run in the high-altitude chamber at Saclay, France.
May 1967	Concorde options reach a total of 74 from 16 airlines.
August 1967	Concorde 001 undergoes resonance testing at Toulouse.
December 11 1967	First prototype Concorde 001 rolled out at Toulouse.
January 1968	Vulcan flying testbed logs first 100 hours in the air.
January 1968	SNECMA variable-geometry exhaust assembly for Olympus 593 engine cleared at Melun-Villaroche for flight in the Concorde prototypes.
February 1968	British Government announces provision of £125 million loan to launch production aircraft and engines.
March 1968	Preliminary engine testing in Concorde 001 at Toulouse.
August 1968	First taxi trials by Concorde 001 at Toulouse.
September 1968	Second prototype Concorde 002 rolled out at Filton.
December 1968	Olympus 593 ground testing reaches 5,000 hours.
March 2 1969	Maiden flight of French-assembled Concorde prototype 001 at Toulouse.
March 1969	Governmental authority given for a total of nine Concorde airframes—two prototypes, two pre-production, two ground test airframes and three series production aircraft.
April 9 1969	Maiden flight of British-assembled Concorde prototype 002 from Filton to Fairford (Gloucestershire).
June 1969	Both Concorde prototypes make first public appearance at Paris Air Show.
July 1969	Annular combustion system design specified for all subsequent Concordes to remove exhaust smoke.
October 1 1969	Concorde 001 first achieves Mach 1.
November 8 1969	First airline pilots fly Concorde 001.
December 1969	Governmental authority given for three more series production Concordes—numbers 4, 5 and 6.
February 1970	Longest single engine test on Olympus 593. Engine ran for 300 hours—a time equivalent to nearly 100 transatlantic Concorde flights.
March 25 1970	Concorde 002 first achieves Mach 1.
April 10 1970	Mr. Wedgwood Benn, British Minister of Technology, makes first VIP flight in Concorde (002).
May 1970	New-design TRA (Thrust Reverser Aft) engine nozzle specified for improved

	weight, aerodynamic and noise qualities on production Concordes.
August 1970	Flights resumed with Olympus 593-3B engines and auto-controlled air intakes.
September 1 1970	Concorde 002 makes first flight on British West Coast test corridor.
September 13 1970	Concorde 002 appears at SBAC Farnborough Air Show and then makes first landing at an international airport—London Heathrow.
November 4 1970	Concorde 001 first achieves Mach 2.
November 12 1970	Concorde 002 first achieves Mach 2.

January 1971	First 100 supersonic flights logged.
April 1971	Four more production Concordes (numbers 6-10) are authorised together with approval for purchase of long-dated materials for the next six production aircraft (numbers 11-16).
May 7 1971	President Pompidou of France becomes the first Head of State to fly supersonic—in Concorde 001.
May 13 1971	Concorde 001 makes first automatic landing.
May 25 1971	Concorde 001 appears at Paris Air Show and then flies to Dakar in West Africa (2,500 miles) in 2 hours 7 minutes—first intercontinental flight.
June 1971	Total Concorde flight test time reaches 500 hours.
	Bench and flight development engine testing totals 10,000 hours.
July 1971	Airline pilots fly at Mach 2.
July 16 1971	Mr. Frederick Corfield—British Minister for Aerospace flies in Concorde 002.
August 1971	Flight clearance obtained for Olympus 593-4 engine standard.
	First 100 bisonic flights logged.
September 20 1971	Concorde 01—the first pre-production aircraft—rolled-out at Filton
September 4-18 1971	Concorde 001 makes trouble-free 15 day tour of South America.
September 1971	Concorde design team awarded special diploma by the Federation Aéronautique Internationale on joint recommendation by Royal Aero Club of Britain and Aero Club de France.
November 12 1971	HRH Princess Anne visits Concorde assembly hall at BAC, Filton.
December 10 1971	Mr. John Davies—British Secretary of State for Trade and Industry—and Lord Carrington—Minister of Defence—fly in Concorde 002. Assurance of continued British Government support for Concorde publicly announced.
December 13 1971	President Pompidou of France flies to the Azores in Concorde 001 to meet President Nixon of the USA.
December 14 1971	US Federal Aviation Agency announces that Concorde will be within American airport noise limits.
December 17 1971	Concorde 01—first pre-production—makes maiden flight from Filton to Fairford.
December 21 1971	All three flying Concordes—001, 002 and 01—on test flights simultaneously.
December 22 1971	Pricing formula for initial Concorde customer airlines announced in British Parliament.

January 6 1972	Three Concordes—001, 002 and 01—together at Fairford.
January 12 1972	HRH Prince Philip The Duke of Edinburgh pilots Concorde 002 during a two-hour supersonic mission.
January 13 1972	BOAC Board of Directors flies in Concorde 002.
February 7 1972	Concorde 002 flies with production undercarriage.
February 12 1972	Concorde 01 flies supersonic.
February 1972	Concorde 02—the second pre-production aircraft—structurally complete at Toulouse.
March 1972	First and second series production Concordes near structural completion at Toulouse and Filton. Work well advanced on major components for Concordes 3-10.
April 13 1972	British and French Governments authorize production of further six series production Concordes (11-16) and announce Concorde 002's mission to Far East and Australia in June.
	Prince Bernhard of the Netherlands, accompanied by Prince Philip, inspects Concordes 002 and 01 at Fairford.
April 22-23 1972	Concorde 002 makes first appearance in Germany—at Hanover Air Show with Mr. Michael Heseltine the new Minister for Aerospace.
April 1972	Delivery of first Olympus 593 Mk.602 to Toulouse for Concorde 02. Total Olympus 593 engine running experience exceeds 20,000 hours.
May 3 1972	Concorde 001 flies from Toulouse to Tangier.
May [illegible] 1972	HRH Princess Margaret, the Duke of Kent, Prince William of Gloucester, and Lord Snowdon fly in Concorde 002.
May 18 1972	One thousand Concorde flying hours now logged by 001, 002 and 01.
May 19 1972	British Prime Minister Edward Heath flies in Concorde 002.
May 25 1972	BOAC announces that it is to order a fleet of five Concordes.



Concordes 001 (left) and 02 (right) at Toulouse, France. These two aircraft, together with Concordes 002 and 01 in Britain, had flown 2,000 hours by mid-1973.

June 2 1972	Concorde 002 leaves Fairford to begin 45,000 mile sales demonstration tour of 12 countries in the Middle and Far East and Australia.
July 1 1972	Concorde 002 returns on time to London-Heathrow on completion of tour.
July 3 1972	HM The Queen (with Princess Anne) inspects Concorde 002 at Heathrow.
July 24 1972	Representatives of The People's Republic of China sign preliminary purchase agreement with Aérospatiale in Paris for two Concordes.
July 28 1972	BOAC signs contract with BAC in London for five Concordes and Air France with Aérospatiale in Paris for four Concordes. Both airlines to take delivery in 1975.
August 10 1972	Concorde 01 returns to Filton for ground programme to bring it up to near full production standard—notably the installation of Olympus 593 Mk.602 powerplants.
August 28 1972	China signs preliminary purchase contract with BAC in Peking for a third Concorde.
September 4-10 1972	Concorde 002 appears daily at the flying display at the SBAC Show at Farnborough and also makes 'show-the-people' flights to several areas of the UK.
September 14 1972	Governmental approval given for the procurement of advance materials for six more series production Concordes (numbers 17 to 22).
September 28 1972	Concorde 02—the second pre-production aircraft—rolled-out at Toulouse.
October 5 1972	Iranair signs preliminary purchase agreement for two Concordes together with an option on a third.
December 11 1972	British Government approves Bill to raise production financial loan from £125 million (see February 1968) to £350 million.
January 10 1973	Concorde 02—second pre-production aircraft—makes maiden flight at Toulouse.
January 22 1973	Concorde 002 leaves Fairford for a 2½-week period of 'hot and high' airfield performance trials at Jan Smuts airport at Johannesburg, South Africa.
January 31 1973	Pan American and TWA decide not to take up their Concorde options—but to 'leave the door open' for further proposals.
February 20 1973	Concorde 002 successfully completes performance trials at Johannesburg and demonstrations at Cape Town.
February 23 1973	Concorde 02 makes 3,728-mile (6,000-km.) non-stop flight from Toulouse to Iceland and return—equivalent to Paris-New York—in 3 hours 27 minutes of which 2 hours 9 minutes at Mach 2.
February 24 1973	Concorde 002 returns to Fairford from South Africa trials.
March 1973	Complex sales option system abolished.
March 3 1973	Concorde 02 makes 3,900-mile (6,280-km.) flight from Toulouse to West Africa and return in 3 hours 38 minutes—equivalent to Frankfurt-New York.
March 14 1973	Arab ambassadors and charges d'affaires make a 2 hour 25 minutes (one hour at Mach 2) flight over the Mediterranean in Concorde 02 from its base at Toulouse.
March 15 1973	Concorde 01 returns from Filton to Fairford after major modification programme, notably the installation of production standard engine air intakes and the smoke-free Olympus 593 Mk.602 engines as in 02.

ABBREVIATIONS

Numerous major organisations and establishments involved in the Concorde programme are commonly known in abbreviated form and those referred to in this *Profile* are listed below:

ARA	Aircraft Research Association
ARB	Air Registration Board
BAC	British Aircraft Corporation
CDC	Concorde Directing Committee
CMB	Concorde Management Board
CEAT	Centre d'Essais Aéronautiques de Toulouse
CEP	Centre d'Essais Propulseur
DoTI	British Department of Trade and Industry
NGTE	National Gas Turbine Establishment
RAE	Royal Aircraft Establishment
SNECMA	Société Nationale d'Etude et de Construction de Moteurs de Aviation
SNIAS	Société Nationale Industrielle Aérospatiale
STAC	Supersonic Transport Advisory Committee

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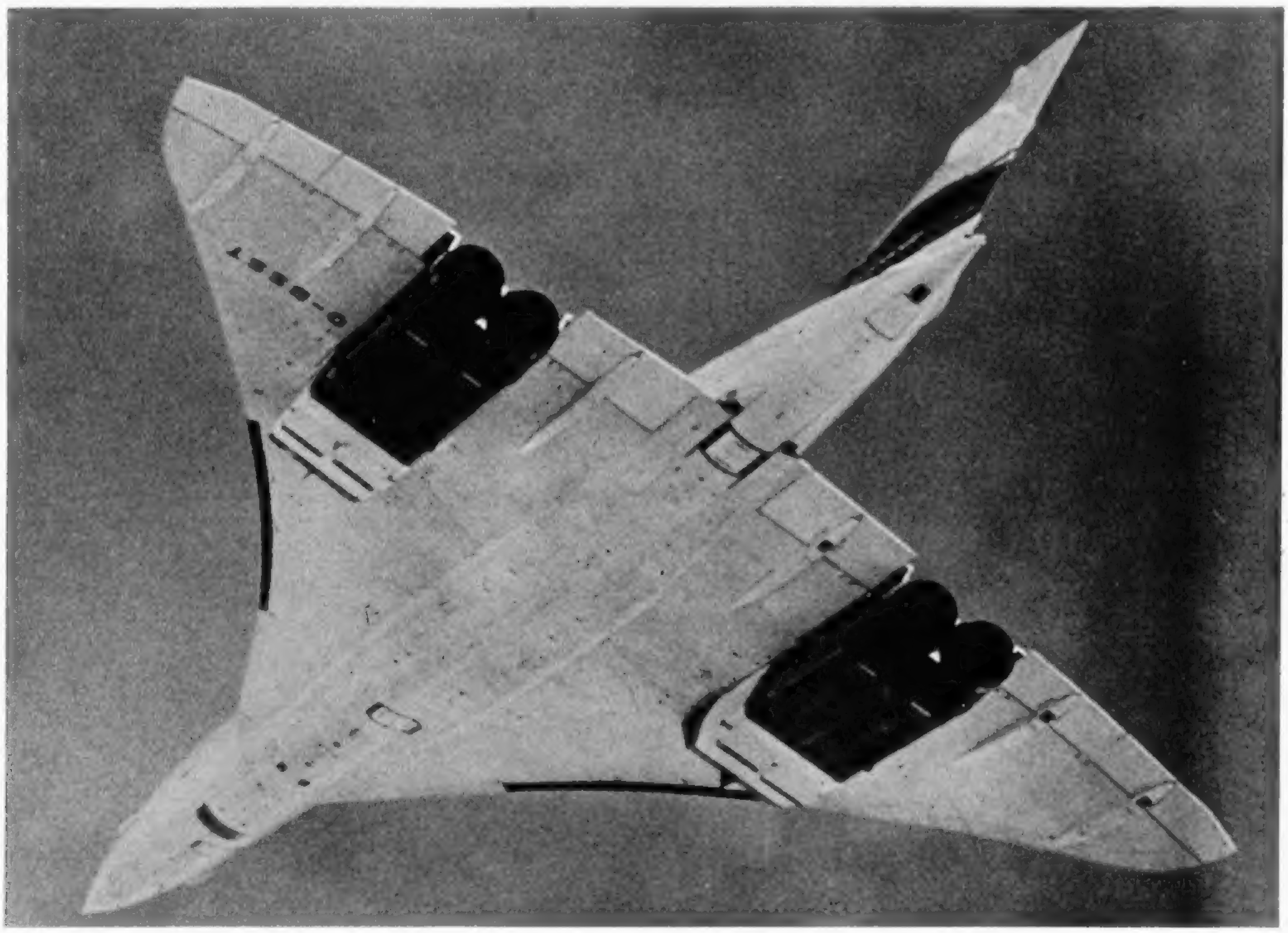

Concorde—the dramatic new airliner shape now dubbed 'Worldshrinker' and poised at the threshold of halving the world in size.